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The Crystal Structure of Graphite in Cast Iron

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SYNOPSIS

The crystal structures of (*a*) graphite extracted from an iron–carbon–silicon alloy prepared from high-purity materials, and (*b*) graphites from a variety of commercial cast irons, have been studied by the X-ray powder method. In all cases the structure was a mixture of the α and β structures found in other graphites of different origin. The proportions of α and β structures present vary considerably in the different forms of graphite, and a correlation between the microscopic appearance and the crystal structure has been established.

The parameters of the unit cells have been measured, and as no variation from the accepted value for pure graphite has been found, it is concluded that the graphite occurring in iron–carbon–silicon alloys and in commercial cast irons is appreciably pure carbon.

Introduction

THE crystal structure of graphite has been studied by numerous investigators,[1–9] using powder, Laue, and rotating single crystal methods. By 1935 the structure was considered to be well established; this structure (α-graphite) is shown diagrammatically in Fig. 1*a*.

In 1936 Finch and Wilman,[10] using electron diffraction methods, found a number of additional diffraction lines which could not be indexed on the basis of the accepted crystal structure. Laidler and Taylor[11] showed that these extra lines could be found on an X-ray powder photograph when a suitable technique was adopted. Several explanations have been advanced to account for the additional lines,[10–13] and the question was finally settled by Lipson and Stokes,[14] who showed that they could be explained by the presence of irregularity in the packing of the layer planes, similar to that found in cobalt.[15]

In graphite, however, the irregularity often recurs at definite intervals over a considerable distance, and this has been confirmed by single crystal work.[16] Graphites which show the additional lines may be considered a mixture of two closely related structures:

(1) The α-graphite structure, shown in Fig. 1*a*, in which the atoms are arranged in layers (within which they form a regular pattern of hexagons) such that neighbouring layers are displaced, as shown in Fig. 1*b*, and alternate layers lie directly beneath each other. This structure can be described in terms of a hexagonal lattice, space group D_{6h}^4, with four atoms in the unit cell. The dimensions of the unit cell are given by Trzebiatowski[9] as $a = 2{\cdot}456$ Å., $c = 6{\cdot}694$ Å.

(2) The β-graphite structure, in which two layers are arranged as in Fig. 1*b* but the next layer is displaced by an equal amount in the opposite direction, as shown in Fig. 1*c*, the pattern being repeated at every fourth layer. This structure can be described in terms of a hexagonal lattice with a unit cell of side length c equal to $\frac{3}{2}$ times that in the α-structure, and it has a space group D_{3d}^5 with unit cell dimensions $a = 2{\cdot}256$ Å. and $c = 10{\cdot}044$ Å., containing six atoms at co-ordinates 0 0 0, $\frac{1}{3}\,\frac{2}{3}\,0$, 0 0 $\frac{1}{2}$, $\frac{2}{3}\,\frac{1}{3}\,\frac{1}{2}$, $\frac{1}{3}\,\frac{2}{3}\,\frac{2}{3}$, $\frac{2}{3}\,\frac{1}{3}\,\frac{2}{3}$.

(Lipson and Stokes[14] point out that this structure is really rhombohedral, with $a = 3{\cdot}636$ Å., $\alpha = 39{\cdot}49°$, and the atoms at $\pm\,(u\,u\,u)$, where $u \simeq \frac{1}{8}$. The space group is $R\bar{3}m$. The parameter u cannot be determined exactly, but the value of $\frac{1}{8}$ was chosen because it gave plane hexagonal rings.)

Owing to the similarity of these structures many of the diffraction lines will coincide, and in a mixed structure only a few additional lines will appear. All the lines may be indexed on the basis of the α-graphite unit cell; the additional lines from the β-graphite will then have fractional l indices which are multiples of $\frac{2}{3}$. The proportion of β-structure present may be estimated by comparing the intensities of the additional lines with the intensities of the lines which arise solely from the α-structure. However, the results so obtained do not agree with the proportions estimated by considering the enhancement of the intensities of the lines common to both structures. Such enhancement arises from disordered packing of the atom layers, and Lipson and Stokes suggested that a certain amount of random disordered packing is present in graphite, over and above that regular disorder caused by the β-structure.

The mixed α- and β-structures have been reported in graphites from widely varying sources, and the

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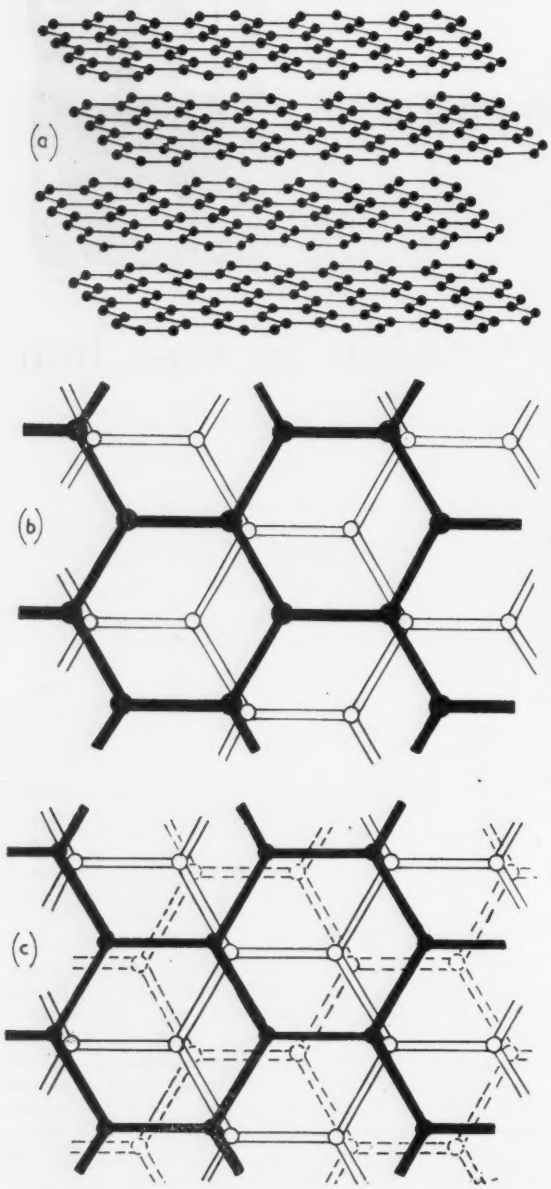

Fig. 1—Structure of α- and β-graphite. (*a*) α-graphite. (*b*) Method of packing layers in α-graphite. (The first layer is represented by heavy lines, and the second layer by thin lines.) (*c*) Method of packing layers in β-graphite. (The first layer is represented by heavy lines, the second by thin lines, and the third by dotted lines.)

proportion of the β-structure appears to vary considerably, from practically nil to about 15% of the total. With the exception of observations made on a kish graphite from a copper steel,[14] reported to give pronounced extra lines of the β-structure, the authors do not know of any recent investigation of the crystal structure of graphite occurring in iron alloys.

EXPERIMENTAL DETAILS

A wide variety of cast irons, containing graphite in many different metallographic forms, has been investigated. The specimens listed in Table I were found to represent the more important forms of graphite ; specimens 1 and 2 are described in detail, whilst specimens 3–9 were commercial irons.

Microstructures of the various irons are given in Figs. 2 and 3.

Specimen 1—Ceylon graphite showed strong extra lines, and was used as a standard of reference to establish that the various treatments to which the iron was subjected did not produce any change in structure.

Specimen 2—Prepared from a high-purity Swedish iron* (containing 0·029% of total impurities other than carbon, silicon, and gases), silicon metal† (containing 99·92% of silicon), and carbon (containing less than 0·07% of ash). The charge, approximately 100 grams, was melted in a recrystallized alumina crucible in a high-frequency furnace. Throughout the melting and cooling cycle (with the exception of two short periods during which excessive degassing of the charge caused a temporary increase) a pressure of less than 10^{-3} mm. of mercury was maintained. To ensure complete degassing of the melt, the alloy was held in the molten state for ¾ hr. The microstructure of a transverse section through the ingot obtained is shown in Fig. 2*a* ; the graphite is entirely of the flake variety, and is predominantly of the form classified by the American Society for Testing Materials[18] as Type *D*, with a few small areas in which Type *A* graphite occurs.

* Presented by the National Physical Laboratory.
† Presented by St. Lawrence Alloys and Metals, Ltd., Quebec.

Table I

DETAILS OF CAST IRONS INVESTIGATED

Specimen	Type of Iron	Form of Graphite	Micro-structure
1	Natural graphite (Ceylon)	...	...
2	High-purity iron–carbon–silicon alloy	Type *D* with a little of type *A*	Fig. 2*a*
3	Commercial high-phosphoric grey iron	Coarse flake type *A*	Fig. 2*b*
4	High-grade grey iron (not inoculated	Medium flake type *A*	Fig. 2*c*
5	Iron inoculated with S.M.Z.*	Flake type *A*	Fig. 2*d*
6	Malleablized white iron	Flake aggregate	Fig. 3*a*
7	Malleablized white iron	Spherulitic	Fig. 3*b*
8	Cerium-treated and inoculated iron No. 1†	Spherulitic and flake	Fig. 3*c*
9	Cerium-treated and inoculated iron No. 2†	Spherulitic and flake	Fig. 3*d*

* S.M.Z. is a proprietary inoculating compound containing about 60% of silicon with small amounts of manganese and zirconium.
† Particulars of these irons[17] are as follows:

No.	Total C, %	Si, %	Mn, %	S, %	P, %	Ce, %
8	3·90	2·96	0·51	0·006	0·024	0·016
9	3·76	3·09	—	0·008	—	0·021

(*a*) High-purity iron carbon–silicon alloy (specimen 2) × 250

(*b*) Commercial phosphoric grey iron (specimen 3) × 250

(*c*) High-grade grey iron, not inoculated (specimen 4) × 150

(*d*) Iron inoculated with S.M.Z. (specimen 5) × 250

Fig. 2—Microstructures of specimens 2–5

(*a*) Malleablized white iron (specimen 6) × 250
(*c*) Cerium-treated and inoculated iron No. 1 (specimen 8) × 150

(*b*) Malleablized white iron (specimen 7) × 250
(*d*) Cerium-treated and inoculated iron No. 2 (specimen 9) × 150

Fig. 3—Microstructures of specimens 6–9

Not less than three different samples of each type of iron listed were examined ; the findings recorded for the nine specimens are fully representative of each type.

Numerous experiments were carried out to determine the most satisfactory method of extracting the graphite from the alloy in a form suitable for subsequent X-ray examination. It was necessary that the crystallographic structure of the graphite should not be affected by the chosen treatment. Riley[19] describes the preparation of various salts of graphite in the presence of an oxidizing agent. These salts decompose easily, causing a rearrangement of the layer planes. Laidler and Taylor[11] showed that boiling in concentrated nitric plus sulphuric acid decreased the intensity of the extra β-lines. The method of extraction finally adopted (which did not produce any change in the structure of Ceylon graphite) consisted of a preliminary anodic treatment of the clean ingot in an aqueous electrolyte containing 4% of hydrochloric acid, at a current density of approximately 20 m.amp./sq. cm. The anodic residue, which was removed by scraping the specimen with a clean penknife, was thoroughly washed in hot water ; X-ray powder photographs of this residue showed a number of graphite lines, together with one or two carbide lines. The residue was then boiled for one hour in 25% caustic soda solution, and was filtered through a No. 52 Whatman paper. After washing, it was transferred to a beaker and boiled for ½ hr. in 50% nitric acid, and was then filtered and washed with hot dilute hydrochloric acid, hot water, cold water, alcohol, and ether successively. The Ceylon graphite standard, when subjected to the same treatment, did not show any diminution in intensity of the additional lines on the powder photograph.

The X-ray powder specimen was prepared by damping the extract with a dilute solution of Seccotine and extruding the mass through a hole in the specimen holder[20]; the specimen was then exposed to filtered cobalt radiation in a 19-cm. Debye–Scherrer camera.

Films were obtained from the extracts prepared from three or more specimens of each type of iron, and two of the films for each of these were carefully measured under a low-power travelling vernier microscope. In addition, a representative film from each type of iron was microphotometered over a range of θ values including the lines $10\bar{1}0$, $10\bar{1}\frac{2}{3}$, $10\bar{1}1$, $10\bar{1}\frac{4}{3}$. A number of films were photometered over the whole range of θ values.

The lines listed in Table II, with the exception of the fractional index lines, were clearly visible on all the films. Table II indicates also the lines attributable to the α-structure, to the β-structure, and to both. The fractional line $10\bar{1}\frac{3}{3}$ was sometimes just visible, and $10\bar{1}\frac{2}{3}$ and $10\bar{1}\frac{4}{3}$ could be clearly seen.

A method of calculating the quantities of β- and disordered structure present in the sample has been described by Lipson and Stokes.[14] However, as only two fractional index lines could be measured with confidence on the films obtained in the present investigation, their method could be applied only to lines over a restricted θ range. The ratios of the observed and calculated relative intensities for the lines $10\bar{1}0$ and $10\bar{1}1$ (which arise only from the α-structure) and for the lines $10\bar{1}\frac{2}{3}$ and $10\bar{1}\frac{4}{3}$ (which are confined to the β-structure) were determined and compared. Thus an estimate was obtained of the proportion of β-structure present. For the Ceylon graphite, which showed all the fractional index lines, the method of Lipson and Stokes was used, the ratios of the observed to calculated intensities for all the lines of the α- and β-structures being plotted against $\sin^2\theta$. Two parallel straight-line plots were obtained. The quantity of β-structure was then estimated by comparing the ordinates of corresponding points on the two lines. The results obtained from these films were the same whether calculated by the modified method or by the complete procedure of Lipson and Stokes. Thus, although the authors' results are probably less accurate than they would be if the latter method could have been employed in all cases, it is unlikely that the error is appreciable.

It is not possible to make an accurate estimate of the amount of disordered structure present, but a qualitative idea can be obtained by comparing the half-intensity breadths of the lines for l non-zero with those for l zero. The results are given in Table III.

Table II

APPROXIMATE VALUES OF $\sin^2\theta$ FOR COBALT RADIATION

Index	$\sin^2\theta$, kX.	Structure
0002	0·0712	Common
$10\bar{1}0$	0·1764	α
$10\bar{1}\frac{2}{3}$	0·1844	β
$10\bar{1}1$	0·1942	α
$10\bar{1}\frac{4}{3}$	0·2084	β
$10\bar{1}2$	0·2476	α
0004	0·2846	Common
$10\bar{1}\frac{5}{3}$	0·3044	β
$11\bar{2}0$	0·5292	Common
$11\bar{2}2$	0·6004	Common
0006	0·6408	Common
$11\bar{2}4$, $10\bar{1}6$	0·8172	Common

Table III

COMPARISON OF HALF-INTENSITY BREADTHS OF DIFFRACTION LINES FOR VARIOUS SAMPLES

Specimen	Type of Iron	β-structure, %	Half-Intensity Breadths			
			$10\bar{1}0$, $10\bar{1}1$	$11\bar{2}0$	$11\bar{2}2$
1	Natural graphite (Ceylon)	13·0	1·85	1·5	1·3
2	High-purity iron–carbon–silicon alloy	7·0	1·85	1·4	1·4
3	Commercial high-phosphoric grey iron	7·4	1·9	1·5	1·5
4	High-grade grey iron (not inoculated)	6·6	2·1	1·5	1·3
5	Iron inoculated with S.M.Z.	6·3	1·9	1·4	1·2
6	Malleablized white iron, flake aggregate	7·4	2·0	1·2	1·1
7	Malleablized white iron, spherulitic	3·5	2·9	1·2	1·7
8	Cerium-treated and inoculated iron No. 1	6·3	2·0	1·3	1·3
9	Cerium-treated and inoculated iron No. 2	4·7	1·7	1·0	1·0

The extract from all specimens containing graphite in flake form (whether of coarse type *A*, fine type *D*, or of intermediate size) gave rise to distinct $10\bar{1}\frac{2}{3}$ and $10\bar{1}\frac{4}{3}$ lines. These specimens all contained between 6·0 and 7·5% of β-structure. The proportion of disordered structure present was about the same as that contained in the sample of Ceylon graphite—probably about 10% of the total. The films obtained from malleable irons containing graphite in the flake aggregate form were indistinguishable from those obtained from flake graphite in common grey irons. However, when the malleable irons contained graphite in the spherulitic form the fractional index lines were very weak, showing that the iron contains much less β-structure (approximately 3·5%). All these films showed excessive line broadening for the lines with l non-zero, this being particularly noticeable with the line $10\bar{1}1$; it is thus clear that spherulitic graphite contains more disordered structure than the flake variety.

The graphite extracted from cerium-treated irons contained greater amounts of β-structure than those in spherulitic malleable irons, but less than the amounts in irons containing flake graphite. The microstructures of cerium-treated irons showed both spherulitic and flake graphite, and the amount of β-structure present in the sample increased as the amount of flake graphite increased. For example, a comparison of Figs. 3*c* and 3*d* shows that specimen 9 contains much less flake graphite than specimen 8, the β-structure contents being 4·7% and 6·3% respectively. From a comparison of the line breadths the amounts of disordered structure present appear to be about the same as those in samples of flake graphite, but from a comparison of the enhancement of the intensities of $\frac{h-k}{3}$ integral lines the amount of disordered structure appears to be slightly greater.

THE LATTICE PARAMETERS

No variation in the spacing of the lines in the diffraction patterns was seen when all the films were compared. Several films, including those obtained from the high-purity alloy (specimen 2), were carefully measured, and the values of $\sin^2\theta$ were compared with those obtained from the film of a high-purity graphite and with the values calculated from the parameters given by Trzebiatowski. The difference between the experimental and calculated values of $\sin^2\theta$ disappeared as θ approached 90°. It is concluded, therefore, that all the samples examined have the same lattice parameters.

Various examples are known of atoms or molecules penetrating between the layer planes of the graphite structure and so forming 'sandwich compounds.' In all cases the formation of such compounds is accompanied by a large change in the dimensions of the unit cell. It was considered unlikely that silicon atoms could penetrate the lattice in this way, and the close agreement of the parameter measurements for samples of graphite extracted from iron–carbon–silicon alloys with those for pure graphite confirm this view.

SUMMARIZED CONCLUSIONS

(1) The crystal structure of any particular microscopic form of graphite is independent of the composition and method of manufacture of the iron.

(2) The regularity of the packing of atom layers in graphites occurring in flake form is different from that in the spherulitic variety, the flake having less disordered structure and more β-structure than the spherulitic.

(3) The crystal structures of graphites occurring in iron alloys are the same as those found in graphites from other sources.

(4) The graphite present in iron alloys does not contain any element, other than carbon, in appreciable quantities.

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The Carbide Phase in Iron–Carbon–Silicon Alloys

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SYNOPSIS

The dimensions of the unit cell of the crystal structure of the carbide phase extracted from a plain carbon steel, a commercial white iron, a high-purity vacuum-melted iron–carbon–silicon alloy, and a similar alloy melted in air, have been measured to a high degree of accuracy by a Debye-Scherrer powder X-ray method. No variation in the dimensions of the cell has been found. It is concluded that silicon in iron–carbon–silicon alloys does not enter the carbide phase, and from this it is deduced that the position commonly accepted for the peritecto-eutectic point in the metastable diagram of this ternary system is probably considerably in error.

THE carbide phase in iron-rich iron–carbon–silicon alloys is known to be closely related to the cementite (Fe_3C) phase in iron–carbon alloys, but the precise composition has been the subject of much speculation. The existence of complex carbides of iron and silicon has been assumed by numerous investigators, including Honda and Murakami,[1] Hanson,[2] and Sawamura.[3] Scheil[4, 5] concluded that the carbide phase does contain silicon, although he considered the data insufficient to substantiate the deduction implicit in the experimental results of Kříž and Pobořil,[6] that it is as much as 4·5%. Kříž and Pobořil[6, 7] also advanced the metallographic evidence that "carbide in iron–carbon–silicon alloys—when etched with hot alkaline solution of sodium picrate—is coloured considerably less than cementite (Fe_3C)." The view that silicon dissolves in the carbide led the present author to attempt to interpret certain unusual microstructures observed by Marles,[8] on the assumption that silicon is capable of segregating within the carbide phase.[9]

The crystal structure of cementite in plain carbon steels has been established by the work of Westgren,[10] Westgren and Phragmén,[11] Hendricks,[12] Lipson and Petch,[13] and Hume-Rothery, Raynor, and Little.[14] The structure, which is orthorhombic with 12 iron atoms and 4 carbon atoms in the unit cell, is fully described by Lipson and Petch. The most accurate determination of the unit cell dimensions was that made by Hume-Rothery, Raynor, and Little, who obtained the values: $a = 4{\cdot}5155$ Å.; $b = 5{\cdot}0773$ Å.; $c = 6{\cdot}7265$ Å.

Petch[15] pointed out that there must be direct iron–iron bonding in the cementite structure, each iron atom having 11 or 12 almost equidistant iron neighbours. The structure was considered as "consisting essentially of a framework of closely packed iron atoms held together by metallic bonding, with the small carbon atoms in the largest interstices, the carbon atoms also being held in position by bonding which has a certain amount of metallic nature, and the whole structure being more dominated by iron–iron than by iron–carbon bonding." On this view, the substitution of iron atoms by other atoms of favourable size factor is possible. It is well established that chromium or manganese atoms can replace iron atoms to a limited extent.[16] Silicon has a size factor favouring its replacement in iron in a structure in which the interatomic distances are of the magnitude found for the iron–iron distances in cementite, and it is therefore possible that such substitution does occur. Alloying of this nature would probably be accompanied by an appreciable change in the dimensions of the unit cell, because of the marked difference in atom size. It would not be possible, however, to deduce from such measurements the amount of silicon entering the structure, since, for example, the substitution of iron atoms by the larger chromium atom causes a decrease in the size of the cell, contrary to expectations.

The only information available for alloys containing carbide and silicon is that provided by Westgren and Phragmén,[11] who, during the course of an investigation into the crystal structure of cementite in steels, examined a 'white annealing iron' and failed to detect any difference between the carbide from this alloy and cementite from steels. However, the accuracy of this early work was not very great, as has been shown by more recent work on the parameters of the unit cell of cementite, and it would be unwise to make any deductions from this isolated determination.

The work described in this paper was carried out to determine accurately the dimensions of the unit cells of various carbides from alloys containing silicon.

EXPERIMENTAL PROCEDURE

Some of the carbides, extracted from 17 different alloys, contained graphite, and as the reflections from graphite are much stronger than those from carbide, the diffraction patterns obtained were considered unsuitable for detailed examination. The patterns from other samples showed rather diffuse lines unsuitable for accurate measurement. Attempts to sharpen the lines by annealing these specimens were not successful, because considerable decomposition took place; the carbide lines, although somewhat sharper, were very faint owing to dilution of the specimen with graphite and ferrite. Only those specimens with massive carbide gave satisfactory diffraction photographs, the best results being obtained from the specimens prepared under controlled rates of cooling from the melt.

Four specimens were finally selected for detailed study, having the following analyses:

Specimen	C, %	Si, %	Mn, %	S, %	P, %	Ni, %	Cr, %
1	1·00	0·15	0·53	0·044	0·041	0·17	0·05
2	3·36	0·96	0·81	0·12	0·06	...	...
3	2·51	1·95	...	...	...	...	...
4	3·49	3·14	...	...	...	...	...

Specimen 1 (*Film* 1)—A hyper-eutectoid steel annealed for 5 hours at 900° C., which had a normal pearlitic structure with a cementite network at the crystal boundaries. This specimen is comparable with the steel used by Hume-Rothery, Raynor, and Little.[14]

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Specimen 2 (*Film* 2)—A commercial 1-in. dia. test bar of chill-cast white iron. The rate of cooling had been insufficient to prevent graphite formation at the centre of the bar, but for a depth of $\frac{3}{8}$ in. from the surface the iron was white with well-formed massive carbide (*see* Fig. 1).

Specimen 3 (*Film* 3)—A sample prepared from high-purity materials :

Hilger iron, J.M. 845
Silicon (St. Lawrence Alloys and Metals, Ltd., Quebec), containing 99·92% of silicon, the major impurity being 0·022% of aluminium
Carbon, graphite with an ash content of 0·07%.

The charge (75 grams) was melted in a recrystallized alumina crucible by means of a coil energized by a valve-oscillating high-frequency unit. A pressure of less than 10^{-3} mm. of mercury was maintained throughout the melting and cooling cycle, except for about three minutes during the early stages of melting, when the pumping speed of the condensation pump was insufficient to handle the large volume of gas produced. The superheated melt was maintained under vacuum for 45 minutes, until the surface was clean and all evidence of gas evolution had ceased. The high-frequency current was then switched off, and after four minutes the vacuum was broken, by which time the specimen had cooled to a temperature of less than 200° C.

Five melts with different silicon contents were treated in this manner, but it was impossible to suppress the formation of graphite in alloys containing more than 2·0% of silicon. The alloy chosen for further study contained 1·95% of silicon and 2·51% of carbon. Metallographic examination of the unetched specimen showed this alloy to be almost completely free from inclusions ; after etching, the carbide was seen to be massive, although there was considerable variation in the size of the carbide areas from the outside to the centre of the specimen. The extent of the variation may be seen by comparing Figs. 2*a* and *b*.

Specimen 4 (*Film* 4)—Attempts were made to increase the rate of cooling of the specimen by breaking the vacuum at an earlier stage and blowing cold air on to the surface of the metal. This treatment produced considerable surface oxidation, without enabling an appreciable increase in silicon content to be made.

To produce a suitable alloy with a higher silicon content, several melts were made in glazed silica crucibles heated in air by means of a graphite sleeve within the high-frequency coil. The metal was cast, in the form of a $\frac{1}{4}$-in. dia. rod, in a cast-iron chill mould. The materials used for these melts were the same as for specimen 3, with the exception of an electrolytic iron, which contained less than 0·05% of total impurities other than carbon, silicon, and oxygen. A metallographic examination revealed remarkably few inclusions and a rather broken-up carbide structure (Fig. 3).

After cleaning the surfaces of the specimens, the carbide was extracted by anodic treatment in 4% hydrochloric acid,[14, 15] and the carbide powders, after careful drying, were passed through a 200-mesh sieve. Other methods of extraction were tried, including that described by Blickwede and Cohen,[17] but all were more laborious without producing any improvement in results. The X-ray powder specimens were prepared by packing the powders into thin-walled cellophane tubes of 0·4 mm. internal diameter. These were mounted in a 19-cm. Debye-Scherrer camera (care being taken to ensure that there was no eccentricity of the specimen when it was rotated), and were exposed to filtered cobalt radiation. Two samples from each specimen were examined, and each film was measured at least twice.

Examination of the films showed that there was very little difference between the pattern from the cementite of specimen 1 and the carbides from the alloys containing silicon. Hence an attempt was made to index the lines by comparing the $\sin^2\theta$ values with the $\sin^2\theta$ values for all possible planes of the cementite (Fe_3C) structure, calculated from the values for the dimensions of the unit cell given by Hume-Rothery, Raynor, and Little.[14] It was found that all the lines on all the films could be indexed with certainty in this way. On careful visual comparison the line spacing on the four films appeared to be identical. Some of the lines were too faint, and others, where overlapping occurred, were too diffuse, for accurate measurement, and thus a selection had to be made. In the investigation by Lipson and Petch,[13] 26 lines in the θ range 20–35° were used for intensity measurements. All these were clear and sharp on the films obtained in the present investigation, and therefore were measured. Later, Petch used five lines in the θ range 47–51°, and in the very accurate work of Hume-Rothery, Raynor, and Little, eight lines in the θ range 69–78° were measured. On films 1 and 3 all the Petch and Hume-Rothery lines were clear and were measured without difficulty, whilst on film 4 the (025) line in the Petch range was not very distinct, and only two Hume-Rothery lines were sufficiently clear to be useful. The pattern on film 2 was similar, but only one Hume-Rothery line could be measured with confidence. The match between the present experimental values of $\sin^2\theta$ and those calculated from the data given by Hume-Rothery, Raynor, and Little, was so close for the high-angle lines that there seemed little point in adjusting the dimensions to obtain an even better match. However, as only a few high-angle lines were available on films 2 and 4, a further examination of the differences in the values of $\sin^2\theta$ was thought necessary. The difference, $\Delta\sin^2\theta$, was therefore plotted against a function linearly proportional to the systematic error in $\sin^2\theta$. As most of the lines lay below 60°, the Bradley-Jay function, $\cos^2\theta$, could not be used. Taylor and Sinclair,[18] and Nelson and Riley,[19] have shown that, with an experimental arrangement such as that used in the present investigation, the error, $\Delta a/a$, in the length of the cube edge of the unit cell of a cubic structure is proportional to

$$\tfrac{1}{2}\left(\frac{\cos^2\theta}{\sin\theta}+\frac{\cos^2\theta}{\theta}\right)$$

for a "medium thickness undiluted" specimen, provided that the camera is accurately constructed and that the specimen is centred to eliminate any eccentricity error. The low-angle limit of proportionality of this function was stated to be 30°. To

Fig. 1—Structure at surface of bar, specimen 2 × 200

Fig. 3—Microstructure of specimen 4 × 600

Fig. 2—Microstructures of specimen 3, showing variation in size of carbide areas × 600

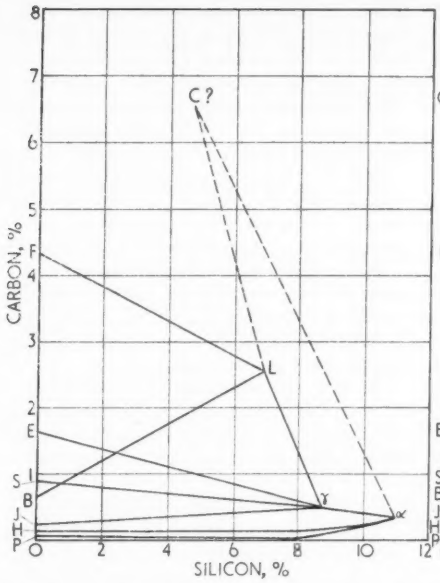

Fig. 4—Basal projection Fe–C–Si diagram (metastable)

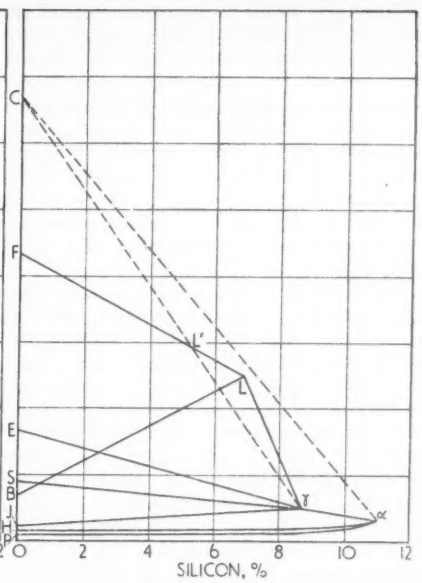

Fig. 5—A possible position of the 4-phase plane

ensure that this function was applicable to the experimental arrangement used in the present investigation, a film from a sample of Hilger iron was examined and was found to yield an excellent straight-line plot down to the lowest angle line (which occurred at $\theta = 26{\cdot}23°$). From this proportionality relationship for the error $\Delta a/a$, a function proportional to the error in $\sin^2\theta$ may be derived. By differentiating the Bragg equation, the error $\Delta d/d$ in the values for the plane spacings may be shown to be proportional to $\frac{\Delta\sin^2\theta}{\sin^2\theta}$. Moreover, since $\Delta a/a$ is proportional to $\Delta d/d$,

$$\frac{\Delta\sin^2\theta}{\sin^2\theta} \propto \tfrac{1}{2}\left(\frac{\cos^2\theta}{\sin\theta} + \frac{\cos^2\theta}{\theta}\right)$$

or

$$\Delta\sin^2\theta \propto \tfrac{1}{2}\sin^2\theta\left(\frac{\cos^2\theta}{\sin\theta} + \frac{\cos^2\theta}{\theta}\right).$$

This form of the function was considered the most convenient, as tables of $\sin^2\theta$ and $\frac{1}{2}\left(\frac{\cos^2\theta}{\sin\theta} + \frac{\cos^2\theta}{\theta}\right)$ are available. The plots (for $\theta > 36°$) of $\Delta\sin^2\theta$ against $\frac{1}{2}\sin^2\theta\left(\frac{\cos^2\theta}{\sin\theta} + \frac{\cos^2\theta}{\theta}\right)$ for the four films under examination showed some scatter, but the best straight line in each case passed through the origin at $\theta = 90°$.

The overlapping high-angle lines $(136)\alpha_1$ and $(251)\alpha_2$ provide a means of testing the accuracy of the chosen axial ratio c/b, as the separation of these lines is very sensitive to a change in the ratio. These lines do not provide so sensitive a test for a/b, because the values of h are similar; however, the overlap (423) (145) contains lines with sufficiently different values of h to be used as a test for this ratio. These two overlaps on films 1 and 3 were examined visually and on a Hilger microphotometer. The overlap $(136)\alpha_1$ $(251)\alpha_2$ showed a curve with a flat top about 0·1 mm. wide, and the lines (423) (145) were seen to be an exact overlap. These results are precisely those required by the chosen axial ratios, and are the same as those found by Hume-Rothery, Raynor, and Little[14] when investigating the cementite structure.

DISCUSSION

As the accurate methods employed in this investigation have failed to detect any change in the unit cell dimensions of cementite when silicon is introduced into iron–carbon alloys, it is concluded that the solubility of silicon in the carbide phase is negligible.

The determinations in the present investigation were carried out at 20° C. Petch,[15] investigating the variation of carbon content of cementite from iron–carbon alloys, was unable to detect any deviation from the 3Fe:1C ratio at temperatures below 680° C., but he did find a small residual variation in the unit cell dimensions at higher temperatures; any changes in the carbon content accompanying the variations were too small to be detected by chemical analysis. He suggested that the variation is produced by carbon atoms leaving the interstices of the lattice. The atomic size of silicon does not permit this type of solution, and no analogy can be drawn. Sometimes the solubility of an element in a substitution type of solution increases with increasing temperature, but this does not seem likely in this case, as the specimens examined were cooled at very different rates. If appreciable solubility existed at higher temperatures, some variation should be found, at least in specimen 4, which was quenched rapidly.

THE IRON–CARBON–SILICON DIAGRAM

Although Petch's work suggests the possibility of a very small variation in the composition of the carbide phase in iron–carbon–silicon alloys at high temperatures, such variation would be too small to be of importance in the following argument, wherein

it is assumed that the phase is of fixed composition corresponding to the formula Fe_3C. If the conventional view of the iron–carbon–silicon system is adopted (*i.e.*, a stable system, iron–graphite–silicon, represented by an equilibrium diagram of the general form described by Scheil,[4] together with a metastable system, iron–carbide–silicon, represented by a diagram of the same form, superposed on it with a slight displacement), then the above conclusion necessitates considerable modification in the values generally attributed to certain crucial points in the iron–carbon–silicon diagram.

Certain alloys in the iron corner of the iron–carbon–silicon system undergo a ternary peritecto-eutectic reaction on cooling; thus the ternary equilibrium diagram contains a quadrilateral plane of constant temperature, representing the 4-phase equilibrium between the melt (L), α-iron solid solution containing carbon and silicon (the point α), γ-iron solid solution containing carbon and silicon (the point γ), and either graphite (in the stable system) or carbide (in the metastable system). This 4-phase plane is shown on a basal projection in Fig. 4. The quadrilateral is defined by the four points representing the compositions of the four phases taking part in the reaction, and as the reaction is invariant these compositions are fixed. Neither the carbide phase in the metastable system nor the graphite phase in the stable system contains silicon,[20] and thus the point C must be placed at 6·69% carbon and 100% carbon respectively. The points α and γ have been arrived at by several methods with fairly good agreement between the results,[6, 7, 21] and probably have approximate values as follows:

	Metastable		Stable	
	Si, %	C, %	Si, %	C, %
α	11	0·3	10·5	0·25
γ	8·7	0·5	7·2	0·4

The point L is determined by the intersection of the binary peritectic line BL and the binary eutectic line FL (*see* Fig. 4). The path of the eutectic line has been extensively investigated,[1, 6, 22–25] and the agreement is surprisingly good, considering the wide variation in the purity of the materials used. The path of the peritectic line has been the subject of only one investigation,[6] and only three experimental points (including the peritectic point of the iron–carbon system) are shown on the curve. Other determinations of the L point have depended on the detection of a small change in direction of the eutectic curve which is supposed to occur at this point. The most reliable experimental values for the position of L are probably those of Kříž and Pobořil, as follows:

	Si, %	C, %
Metastable	6·9	2·61
Stable	6·4	2·54

From the general theory of equilibrium diagrams it may be shown that, for a reaction of the type under consideration, the points C, α, γ, and L must lie at the corners of a quadrilateral which cannot contain a re-entrant angle. For the stable system this condition is satisfied if the values detailed above are adopted. For the metastable system, however, these values produce a re-entrant angle at L (*see* Fig. 5). This discrepancy can be accounted for in two ways. There may be an appreciable error in the experimental values for the points in the metastable system; if this is so, the greatest error is probably in the position of L (for reasons which have been indicated earlier). If it is assumed that the path of the binary eutectic, as shown in Fig. 5, is approximately correct, the maximum possible silicon content at L appears to be about 5%, with a corresponding carbon content of about 2·9% (L', Fig. 5). Alternatively, the difficulty would not arise if the theoretical rules applicable to equilibrium diagrams were considered to be invalid when applied to metastable systems. The published data for the metastable part of the double diagram could be regarded merely as a representation of the conditions existing when rather impure alloys are appreciably under-cooled.

A new experimental determination of the points in both the metastable and stable systems is obviously necessary, and is being carried out at Liverpool, using high-purity materials melted *in vacuo*.

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The Development of Low-Carbon N-155 Alloy for Gas-Turbine Construction

By W. O. Binder

SYNOPSIS

The early development of low-carbon N-155 alloy (nominal composition : Carbon 0·12%, nickel 20%, chromium 20%, cobalt 20%, tungsten 2%, niobium 1%, molybdenum 3%, nitrogen 0·12%, remainder iron) is described, and a study of the influence of hot cold-working, solution annealing, and precipitation hardening on the structure, room-temperature strength, ductility, and impact resistance of the material is reported. Properties at elevated temperatures are reviewed, and creep curves for various stresses at 650°, 730°, and 815° C., extending in some cases from 10,000 to 32,000 hr., are presented ; the amount of scatter in stress-rupture test results is investigated and statistically examined. Previous fabricating treatment has a marked influence on the properties of the alloy. Hot cold-working may be utilized for improving hot strength at temperatures up to 650° C., but for uniformity of results the hot cold-working step should be preceded by a solution anneal between 1060° and 1150° C. For high strength at temperatures in excess of 650° C. solution heat-treatment at 1090–1230° C. is recommended. The alloy is subject to some precipitation-hardening during exposure to temperatures in the range 650–980° C., resulting in an increase in strength and a decrease in ductility and toughness at room temperature ; though precipitation-hardening heat-treatments are not generally applied in practice, they improve hot-ductility. A study of the properties of sheet indicates that they do not differ significantly from those of bar stock, and the formability of the alloy is shown to be comparable to that of type 347 stainless steel (niobium-stabilized 18/8).

Introduction

THERE are many considerations influencing the design of a wrought alloy for gas-turbine construction. Such an alloy must lend itself to economical manufacture, metallurgical control, and fabrication, and must also meet the severe requirements of service, factors often calling for contradictory qualities. The problem is complicated because the methods available for improving hot strength frequently impart limitations in manufacture and fabrication, affecting the utility of the alloy from a commercial standpoint. A given alloy therefore represents a compromise, and the difference between alloys developed for gas-turbine construction reflects differing points of view on the importance of certain qualities.

Exact requirements for a gas-turbine high-temperature alloy have not been fully defined, but practical experience indicates that the material must possess high strength at temperatures as high as 980° C. and that it must be resistant to oxidation and carburization over the operating temperature range. In addition to good creep and rupture strength, the alloy must show resistance to thermal and mechanical fatigue and have low notch sensitivity and a slow rate of embrittlement, to permit long-time operation under the influence of stress and temperature. The material should also have good hot-working characteristics for economical production into forgings, rolled bars, sheets, and strip, which means that it must be relatively free from abnormal inclusion formation and from segregation and unsoundness in ingot form ; in general, the two last-mentioned qualities are favoured by relatively high iron and low carbon contents.

Since many components of a gas turbine are fabricated by welding, the alloy should be adaptable to all types of welding processes, in order to permit the use of the most favourable fabrication techniques. Another important requirement is high ductility at room temperature. Many components are fabricated from sheet metal by stamping, drawing, and spinning operations, and these methods of forming demand a high degree of cold-ductility. Experience indicates that alloys having less than 35% elongation in 2 in. or 50% in 0·2 in. are generally unsatisfactory for complicated forming operations.[1]

To facilitate fabrication and metallurgical control, the solution heat-treating temperature required to impart optimum hot strength should not be too high. Excessively high temperatures introduce surface-oxidation problems which are costly to control. Neither should drastic quenching after heat-treatment be required, as warpage and dangerous internal stresses may accompany such an operation. Compulsory ageing after solution heat-treatment is also undesirable but is not a limiting requirement, and, finally, the alloy should be amenable to hot cold-working.

In view of the pressing need for improved wrought high-temperature alloys for gas-turbine construction at the beginning of World War II, the Union Carbide and Carbon Research Laboratories, Inc., undertook a broad programme of research in this field. This investigation led to the development of low-carbon N-155 alloy, the nominal content of which is as follows :

	%
Carbon	0·12
Silicon	0·5
Manganese	1·5
Nickel	20
Chromium	20
Cobalt	20
Tungsten	2
Niobium	1
Molybdenum	3
Nitrogen	0·12
Iron	Remainder

The properties of N-155 alloy indicate that it should be useful for service at elevated temperatures.

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Some of the high-temperature characteristics and fabricating properties of the material of interest to metallurgists are described in the present paper.

EARLY DEVELOPMENT

When the work was started there was an urgent demand for a turbo-supercharger-disc material having a 1000-hr. life stress of at least 18 tons/sq. in.* at 650° C., and a room-temperature yield strength of 45 tons/sq. in. at 0·2% offset. High elastic strength was required to counteract plastic yielding near the hub section in the case of overstressing in service. Yield strength is employed as a design-stress criterion in the hub section of the disc, as it operates at moderately low temperatures. It was anticipated that the rim would reach a temperature of 650° C., and, since the disc was to rotate at extremely high speeds, adequate creep resistance was desired to offset the high stresses developed in this section owing to the centrifugal action of the blades. At approximately the same time the design and development of jet engines for aircraft propulsion became very urgent, and the work was subsequently broadened to cover materials in all forms capable of withstanding high stresses at temperatures up to 870° C., for gas-turbine construction.

The aim of the investigation was to evolve a high-strength austenitic-type alloy containing a major proportion of iron which would not become excessively brittle after extended periods of exposure at elevated temperatures. An austenitic structure was chosen, as it is inherently ductile, strong at elevated temperatures, adaptable to work-hardening processes, and capable of forming precipitation-hardening systems improving hot strength. A high proportion of iron was considered desirable because supplies of this element are plentiful and because it helps to provide sound ingots.

While various combinations of chromium, nickel, cobalt, and iron may be chosen to form such a structure, the chromium content must be at least 12%, and preferably should be higher for satisfactory oxidation resistance in service. Good oxidation resistance is also of vital importance during fabrication, particularly when producing sheet and strip, as excessive scaling of these products during fabrication may be detrimental to their quality. To stabilize the austenitic structure, nickel and cobalt are essential. The presence of nickel increases hot strength, prevents excessive work-hardening, and inhibits loss of ductility and toughness after prolonged heating in the service temperature range. Like nickel, cobalt stabilizes the austenitic structure and helps to prevent excessive embrittlement. In addition, cobalt improves hot-workability and has a marked beneficial effect on hot strength. The formation of austenite is promoted by the addition of carbon and nitrogen, which improve the yield strength of the austenitic matrix ; moreover, the use of nitrogen avoids the deleterious influence on ductility which normally accompanies an increase in carbon.

The choice of elements imparting to the austenitic matrix precipitation-hardening and alloying effects favourable to high-temperature strength in conjunction with carbon and nitrogen depends upon melting, casting, and other fabrication considerations. The availability of molybdenum indicated that a good portion of the strength should be derived from this element, but from the standpoint of hot-workability and embrittlement it appeared advisable to augment its action with tungsten, which is less harmful in this respect. Alloys containing niobium, tantalum, vanadium, titanium, aluminium, and boron in conjunction with molybdenum and tungsten were investigated, as these elements also impart high-temperature strength. Experience with niobium indicated that it might serve to inhibit excessive loss of toughness owing to carbide precipitation, as well as improving hot strength. The use of easily oxidizable elements was held to a minimum to avoid fabrication problems resulting from poor recovery and unsatisfactory surface.

The initial experiments were carried out on basic-lined induction-furnace melts weighing 15–30 lb. each, cast into 2-in. square ingots. The alloys were deoxidized with 1·5% of manganese and about 0·4% of silicon. In the beginning the testing was confined to hot cold-worked material in an attempt to produce an alloy for turbo-supercharger discs having the combination of properties specified, cold-worked material being chosen in order to obtain the high elastic properties required ; fortunately, the application of cold-work improves strength at elevated temperatures as well as at room temperature. The

* Throughout the present paper all units expressed in tons refer to tons of 2240 lb.

Table I

COMPOSITION RANGE OF ALLOYS SELECTED ON BASIS OF INITIAL INVESTIGATION

Element	Alloy 1 (N-153)	Alloy 2 (N-154)	Alloy 3 (N-155)	Alloy 4 (N-156)
Carbon, %	0·30– 0·40	0·30– 0·40	0·30– 0·40	0·30– 0·40
Silicon, %	0·60 max.	0·60 max.	0·60 max.	0·60 max.
Manganese, %	1·25– 1·75	1·25– 1·75	1·25– 1·75	1·25– 1·75
Nickel, %	15·00–16·00	24·00–26·00	20·00–22·00	33·00–35·00
Chromium, %	15·00–16·00	15·00–16·00	20·00–22·00	15·00–16·00
Cobalt, %	12·00–14·00	19·00–21·00	20·00–22·00	23·00–25·00
Tungsten, %	1·75– 2·25	1·75– 2·25	1·75– 2·25	1·75– 2·25
Niobium, %	0·80– 1·10	0·80– 1·10	0·80– 1·10	0·80– 1·10
Molybdenum, %	2·75– 3·25	2·75– 3·25	2·75– 3·25	2·75– 3·25
Nitrogen, %	0·04– 0·08	0·04– 0·08	0·08– 0·12	0·04– 0·08
Iron	Remainder	Remainder	Remainder	Remainder

Table II

STRESS-RUPTURE PROPERTIES OF N-153, N-154, N-155, AND N-156 ALLOYS AT 650° C. AND 730° C. IN HOT COLD-WORKED CONDITION

Alloys and Treatment	Melt Composition										Room Temp. Yield Strength at 0·2% Offset, tons/sq. in.	Rupture Stress, tons/sq. in.			
												650° C.		730° C.	
	C, %	Si, %	Mn, %	Ni, %	Cr, %	Co, %	W, %	Nb, %	Mo, %	N, %		100 Hr.	1000 Hr.	100 Hr.	1000 Hr.
Alloy N-153	0·38	0·52	1·78	14·98	16·20	12·82	2·19	1·06	3·01	0·07	...	...	...	...	...
Solution heat-treated 1 hr. at 1150° C. and A.C.	...	...	...	...	...	...	...	...	...	...	25·45	22·32	16·96	12·50	...
Hot cold-worked about 25% at 925° C.	...	...	...	...	...	...	...	...	...	...	53·13	24·11	17·86	12·72	8·48
Hot cold-worked about 25% at 650° C.	...	...	...	...	...	...	...	...	...	...	62·95	26·80	19·20	13·84	10·71
Alloy N-154	0·32	0·61	1·58	23·95	16·17	20·95	2·20	1·03	3·06	0·07	...	...	...	...	...
Solution heat-treated 1 hr. at 1150° C. and A.C.	...	...	...	...	...	...	...	...	...	...	24·56	21·43	15·63	...	...
Hot cold-worked about 25% at 925° C.	...	...	...	...	...	...	...	...	...	...	54·46	24·11	20·54	12·50	8·48
Hot cold-worked about 25% at 650° C.	...	...	...	...	...	...	...	...	...	...	65·63	25·90	18·75	12·72	8·93
Alloy N-155	0·32	0·57	1·54	20·80	21·08	20·54	2·18	0·98	3·00	0·11	...	...	...	...	...
Solution heat-treated 1 hr. at 1150° C. and A.C.	...	...	...	...	...	...	...	...	...	...	28·13	23·22	17·41	...	...
Hot cold-worked about 25% at 925° C.	...	...	...	...	...	...	...	...	...	...	60·27	26·34	20·54	12·50	8·93
Hot cold-worked about 25% at 650° C.	...	...	...	...	...	...	...	...	...	...	67·41	28·13	20·54	13·40	8·70
Alloy N-156	0·33	0·57	1·48	33·23	15·66	23·69	2·10	1·03	3·02	0·07	...	...	...	...	...
Solution heat-treated 1 hr. at 1150° C. and A.C.	...	...	...	...	...	...	...	...	...	...	25·45	21·88	14·73	11·61	...
Hot cold-worked about 25% at 925° C.	...	...	...	...	...	...	...	...	...	...	54·91	25·00	19·64	12·95	9·82
Hot cold-worked about 25% at 650° C.	...	...	...	...	...	...	...	...	...	...	66·52	26·34	19·64	13·40	9·15

A.C. = air-cooled

work-hardening was carried out at elevated temperatures below the recovery temperature of the alloy in order to decrease the resistance of the metal to deformation, a process known as hot cold-working, and applicable to relatively heavy sections. In these tests the hot cold-working was conducted in the temperature range 1050–760° C., on as-forged bars which had previously been reduced to about 25% oversize by successive working and reheating in the temperature range 1150–1050° C. This procedure was utilized as there were indications that it would give satisfactory ductility in the high-temperature tests.

No attempt will be made in the course of the present paper to report or discuss in detail the results of the many tests carried out before the composition of N-155 alloy was selected.* Needless to say a marked variability in casting characteristics and hot-workability was noted, as well as differences in strength, ductility, and oxidation resistance, and the tests clearly showed that many factors required investigation. The experience gained in the initial test work led directly to the formulation of the alloys subsequently designated N-153, N-154, N-155, and N-156, having the composition ranges shown in Table I. These alloys were made in a 750-lb. basic-lined arc furnace, and the melts were cast into the form of 8-in. square ingots weighing about 600 lb. each and several 3-in. square ingots weighing 45 lb. each, to provide ingots for the production of experimental supercharger discs and bar stock for confirmation tests. The 8-in. square ingots were hammer-forged under commercial conditions into turbo-supercharger discs, and the 3-in. square ingots were hammer-forged to $\frac{7}{8}$-in. square bars which were subsequently heated for 1 hr. at 1150° C. and air-cooled, then reduced about 25% in area by hot-rolling at 650° and 925° C. The results of the confirmatory tests are given in Table II.[2, 3]

The strength of the alloys at 650° and 730° C. more than fulfilled expectations, but the tests failed to reveal any marked superiority of the high-nickel N-154 and N-156 alloys over the lower-nickel N-153 and N-155 alloys, and as operating conditions in gas-turbine sheet-metal components are more severe than in the disc itself the work was concentrated on the N-155 alloy, which has higher chromium content and better hot-workability, particularly when compared with the N-156 alloy. It was also decided to continue with the lower-chromium and higher-iron N-153 alloy, as this alloy appeared to be applicable for service temperatures up to about 760° C.; the properties of the N-153 alloy have been described elsewhere,[4] and will not be considered here.

While these results indicated that N-155 alloy, containing 0·35% of carbon, would be satisfactory for service over a wide range of temperatures, experience with other austenitic alloys indicated that lowering the carbon content of the alloy would improve hot-workability, increase cold-ductility, reduce the tendency of the alloy to lose ductility and toughness when exposed to elevated temperatures, and favour the production of sheet and strip, which were urgently needed to construct many of the gas-turbine components. With these improvements in mind, tests reported in Table III were performed on lower-carbon alloys, and it will be noted that lowering carbon to about 0·1% increases the ductility of the alloy and at 650° C. has relatively no effect on hot

* Some of the earlier test results have been published in reference 2.

Table III

EFFECT OF LOWERING CARBON ON DUCTILITY AND STRESS-RUPTURE PROPERTIES OF THE N-155 ALLOY

C, %	N, %	Condition of Metal	Room-Temp. Tensile Properties				S.T.T. at 650° C.			Test Temp., °C.	Stress Causing Rupture in		Estimated Ductility at Fracture		Reference
			Tensile Strength, tons/sq. in.	0·2% Yield Strength, tons/sq. in.	Elongation, %	Reduction in Area, %	Tensile Strength, tons/sq. in.	Elongation, %	Reduction in Area, %		100 Hr., tons/sq. in.	1000 Hr., tons/sq. in.	100 Hr.	1000 Hr.	
0·32	0·11	(1)	71·65	61·83	17	29	47·54	15	29	650	26·34	20·54	10	5	3
0·32	0·11	(2)	75·00	67·41	14	30	52·23	11	25	650	28·13	20·54	4	2	3
0·13	0·11	(3)	59·60	42·09	33	56	39·96	29	31	650	25·90	21·43	14	14	3
0·07	0·15	(3)	63·71	52·01	16	45	47·86	22	49	650	26·34	21·88	10	15	...

(1) Forged to $\frac{3}{8}$-in. square bar, heated 1 hr. at 1150° C., air-cooled, heated to 925° C., and reduced about 25% in area by hot-rolling
(2) Forged to $\frac{3}{8}$-in. square bar, heated 1 hr. at 1150° C., air-cooled, heated to 650° C., and reduced about 25% in area by hot-rolling
(3) Hot cold-worked about 25% at temperatures between 1150° and 760° C., in as-forged condition

strength. The carbon content of the low-carbon alloy was subsequently set at 0·2% maximum, and the low-carbon alloy was designated low-carbon N-155, to differentiate it from the 0·35% carbon alloy. The remainder of the present paper deals with the hot-working, heat-treatment, and mechanical properties of the low-carbon alloy.

PROPERTIES OF LOW-CARBON N-155 ALLOY

Composition and Hot-Working

The composition range adopted for production of the low-carbon N-155 alloy is as follows :

	%
Carbon	0·2 (max.)
Silicon	1 (max.)
Manganese	1–2
Nickel	19–21
Chromium	20–22·5
Cobalt	18·5–21
Tungsten	2–3
Niobium	0·75–1·25*
Molybdenum	2·75–3·75
Nitrogen	0·1–0·2
Iron	Remainder

* Present aeronautical materials specifications (S.A.E.) permit tantalum to be substituted in part for niobium.

In Table IV the hot-ductility of low-carbon N-155 alloy in the temperature range 1150–1260° C. is compared with A.I.S.I. type stainless steel (niobium-stabilized 18/8 steel) by means of short-time tensile and hot-twist tests.[5, 6] At these temperatures the ductility of the alloy is somewhat less than that of type 347 stainless steel, although at 1200° C. both alloys exhibit about the same number of twists before failure ; the alloy is, however, much stiffer and stronger than type 347 steel. These laboratory tests, which indicate 1200° C. as a maximum temperature for good hot-workability, correlate surprisingly well with forging and rolling tests on ingots.

In practice, the ingots are thoroughly soaked before hot-working, to avoid centre bursts and other difficulties due to non-uniform heating. The finishing temperature is governed by the size and shape of the section, as the metal stiffens rapidly below 980° C. The maximum initial rolling temperature for plate and sheet is held at about 1175° C. to avoid excessive scaling.

Table IV

HOT-DUCTILITY TESTS ON LOW-CARBON N-155 ALLOY AND A.I.S.I. TYPE 347 STAINLESS STEEL IN AS-FORGED CONDITION

Samples held ½ hr. at temperature before testing. Average testing speed 0·04 in./min.

Test Temp., °C.	Tensile Strength, tons/sq. in.	Elongation in 1·5 in., %	Reduction in Area, %	Number of Twists to Failure	Max. Torque, in.-lb.
		Type 347 Stainless Steel			
1200	1·28	50	37	38	410
1260	0·90	37	44	28	330
		Low-Carbon N-155 Alloy			
1150	...	...	...	31	980
1200	2·13	34	33	34	650
1235	1·54	40	45	17	510
1260	1·59	22	36	6	470

Heat-Treatment

The properties of the low-carbon N-155 alloy at elevated temperatures are greatly altered by heat-treatment. As previously mentioned, strain-hardening may be utilized as a means of improving the strength of the alloy at elevated temperatures, and optimum strength at temperatures not greatly exceeding 650° C. is obtained by hot cold-working. Freeman and co-workers[7] have recently completed a very comprehensive investigation of the factors affecting the hot strength and ductility of the alloy at 650° C. They advocate hot cold-work below 760° C. in amounts of 10–15% after solution heat-treatment for the best rupture strength, but to preserve good ductility they limit the solution heat-treatment to between 1060° and 1150° C. Ageing before or after hot cold-working was found to improve the hot-ductility materially, and may be quite beneficial to hot strength, particularly at high stress levels. While hot cold-working after hot-working gave the best combination of properties, such treatments were not recommended, owing to the difficulty of controlling the process.

The extent to which strain-hardening may be utilized for improving the hot strength of the alloy depends on the conditions of service. When these conditions cause recovery of the metal the creep resistance of the alloy in the strain-hardened condition may vary widely, as shown in Fig. 1.[8] The variations are due to microstructural differences resulting from fabricating conditions, although none of the working practices employed in these tests were greatly different from the standpoint of commercial practice. To gain high strength at temperatures in excess of 650° C., where the alloy is susceptible to recovery after strain-hardening, solution heat-treatment is necessary. The marked improvement in creep strength owing to solution heat-treating at temperatures of about 1200° C. is demonstrated in Fig. 2, which shows the results of tests at 815° C. and 3·57 tons/sq. in. stress.

For service temperatures in excess of 650° C. the alloy is solution heat-treated at temperatures in the range 1090–1230° C. and cooled rapidly. The cooling rate should be as rapid as possible, and in the case of heavy sections it is advisable to retard the decomposition of the solid solution by water- or oil-quenching. While somewhat greater strength may be obtained by heat-treating at 1260° C., at this temperature the alloy is subject to excessive surface scaling, grain growth, and low hot-ductility. As surface oxidation and grain growth are particularly detrimental to the quality of thin sheet and strip, these products are solution heat-treated between 1120° and 1175° C.

In practice, precipitation heat-treatments are generally not applied to the alloy. Under certain conditions, however, such treatments may be beneficial, as they greatly improve hot-ductility, remove stresses, and increase yield strength somewhat. Heat-treatments for removing stresses are normally of short duration and do not exceed 2–4 hr. The combination of properties made available by ageing offers an interesting field for further investigations in connection with this alloy.

Microstructure

The microstructure of low-carbon N-155 alloy after solution heat-treatment at 1090–1280° C. is illustrated in Fig. 4.[4] Here it is seen that as the temperature is raised there is a gradual increase in grain size, with some tendency for abnormal grain growth in localized areas at temperatures above 1200° C. Heat-treatment at 1250–1280° C. causes almost complete solution of all phases except niobium carbide, which is only partially dissolved. While maximum hot strength was obtained after heat-treating at 1250° C., practical considerations lead to the recommendation of a lower temperature. For example, the abnormal grain growth occurring above 1200° C. prohibits the use of this temperature when optimum hot-ductility or deep-drawability is required.

On heating the alloy at temperatures between 650° and 980° C. precipitation-hardening occurs, causing the alloy to increase somewhat in hardness and strength, and decrease in ductility at room temperature; it is believed that this precipitation has a significant effect on the hot strength of the metal. The appearance of the microstructure of the alloy after 1 week at 650–815° C. is shown in Fig. 5.[4] At 650° C. the precipitate is confined chiefly to the grain boundaries and the particles are in a finely dispersed state. The dispersion of the precipitate at 730° C. is

Fig. 1—Variations noted in creep resistance of low-carbon N-155 alloy at 815° C. and 3·57 tons/sq. in. stress in hot cold-worked condition

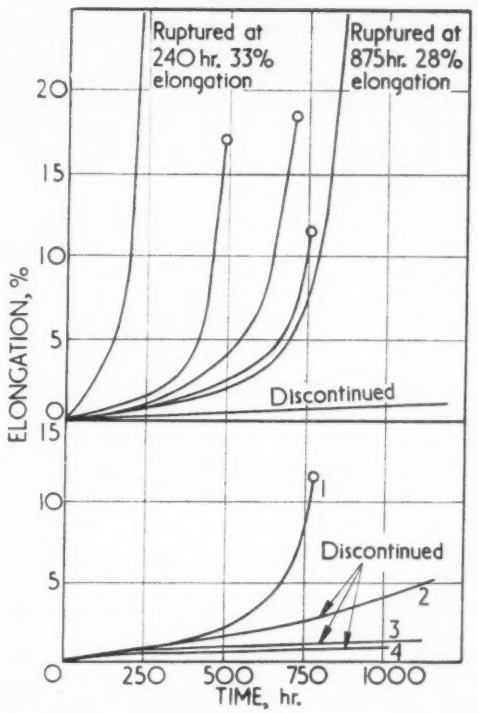

Fig. 2—Effect of heat-treatment on creep resistance of low-carbon N-155 alloy at 815° C. and 3·57 tons/sq. in. stress. Curve 1: heated 2½ hr. at 825° C. Curve 2: heated 1 hr. at 1000° C. Curve 3: heated 1 hr. at 1100° C. Curve 4: heated 1 hr. at 1225° C. All air-cooled

Table V

PHYSICAL PROPERTIES OF LOW-CARBON N-155 ALLOY

Property	Test Temp., °C.	Value	Reference
Density, g./c.c.	20	8·198	9
Specific heat, cal./g.	20	0·112	10
Specific resistance, microhm-cm.	20	93	...
Coefficient of linear expansion (20–θ° C.), cm./cm./° C.	20–316	$15·7\times10^{-6}$	9
	20–427	$16·1\times10^{-6}$	9
	20–538	$16·4\times10^{-6}$	9
	20–650	$17·0\times10^{-6}$	9
	20–815	$17·7\times10^{-6}$	9
	20–870	$17·9\times10^{-6}$	9
	20–980	$18·0\times10^{-6}$	9
Thermal conductivity, g. cal./sec./sq. cm./° C.	200	0·0349	...
	300	0·0380	...
	400	0·0414	...
	500	0·0435	...
	600	0·0480	...
Coefficient of static friction:			
Annealed and pickled surface	20	0·21*	10
Oxidized 30 min. at 870° C.	20	0·62*	10
Oxidized 30 min. at 870° C.	870	0·62*	10

* Average for loads of 5–40 lb./sq. in.

somewhat coarser than at 650° C., and the precipitate is easily visible in the grains and grain boundaries. At 815° C. the precipitate is even coarser. Although not shown, the growth of the particles continues with increasing temperature until the temperatures for solution of the precipitate are reached.

Prolonged heating at 815° C., and to a lesser extent at 650° and 730° C., tends to coagulate the precipitated particles. Figures 6 and 7 show the appearance of the precipitate developed after various periods of time at 815° and 730° C. under stress. Here again it is seen that the precipitate forming at 815° C. is visibly coarser than that formed at 730° C. At 815° C. the initial precipitation occurs chiefly around the grain boundaries of the alloy, in the form of finely dispersed

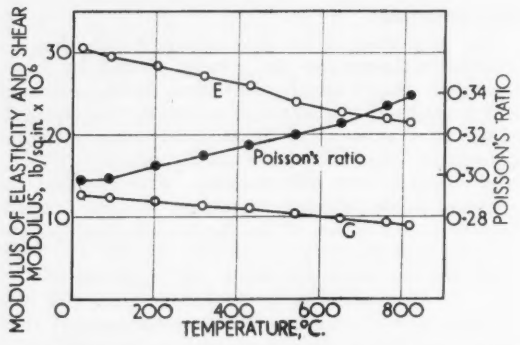

Fig. 3—Variation with temperature of Young's modulus of elasticity, modulus of rupture, and Poisson's ratio

particles, with a fewer number of particles forming in the grain areas. The precipitate is considerably coarser after 1500 hr. at 815° C. than after 22 hr., and it is more uniformly distributed in the matrix metal. The grain boundaries are also less easily distinguishable, and show evidence of widening owing to coagulated particles of precipitate. Increasing the time of heating at 815° C. to 5500 hr. causes further coagulation and formation of the precipitate. The grain boundaries have widened to a marked extent and appear to consist of a solid chain of coagulated particles. Ageing at 730° C. for 12,000 and 32,000 hr., respectively, resulted in a similar type of precipitation, but, as shown in Fig. 7, there is less coagulation of the precipitate at this temperature than at 815° C.

Some work has been carried out on the identification of the phases present in the alloy after long ageing at 730° and 815° C. by means of X-ray analysis of residues extracted electrolytically, the electrolyte consisting of a 5% hydrochloric acid solution. The residue was separated by decantation and washed with distilled water, and was then treated with a 70/30 mixture of concentrated ammonium hydroxide and 30% hydrogen peroxide, after which it was washed with distilled water and finally with alcohol, and dried thoroughly in air. Debye-Scherrer X-ray diffraction patterns were prepared using the radiation from a chromium target. The results of the X-ray examination revealed the following data :

(1) Solution heat-treating at 1200–1280° C. causes practically complete solution of all the phases except NbC, which is only partially dissolved.

Table VI

MECHANICAL PROPERTIES OF LOW-CARBON N-155 ALLOY AT ROOM TEMPERATURE

Treatment	Tensile Strength, tons/sq. in.	Yield Strength, at 0·2% Offset, tons/sq. in.	Elongation, %	Reduction in Area, %	Izod Impact Value, ft.-lb.	Brinell Hardness Number
Heated 1 hr. at 1270° C. and W.Q.	51·38	23·84	58	67	102	183
Heated 1 hr. at 1270° C. and W.Q., heated 24 hr. at 815° C. and A.C.	54·19	28·40	36	37	...	207
Hot cold-worked 21-in. dia. × 3¼-in. thick disc, centre section (reference 11)	52·50	31·92	30	48	45–60*	211

* Charpy impact values
A.C. = air-cooled; W.Q = water-quenched

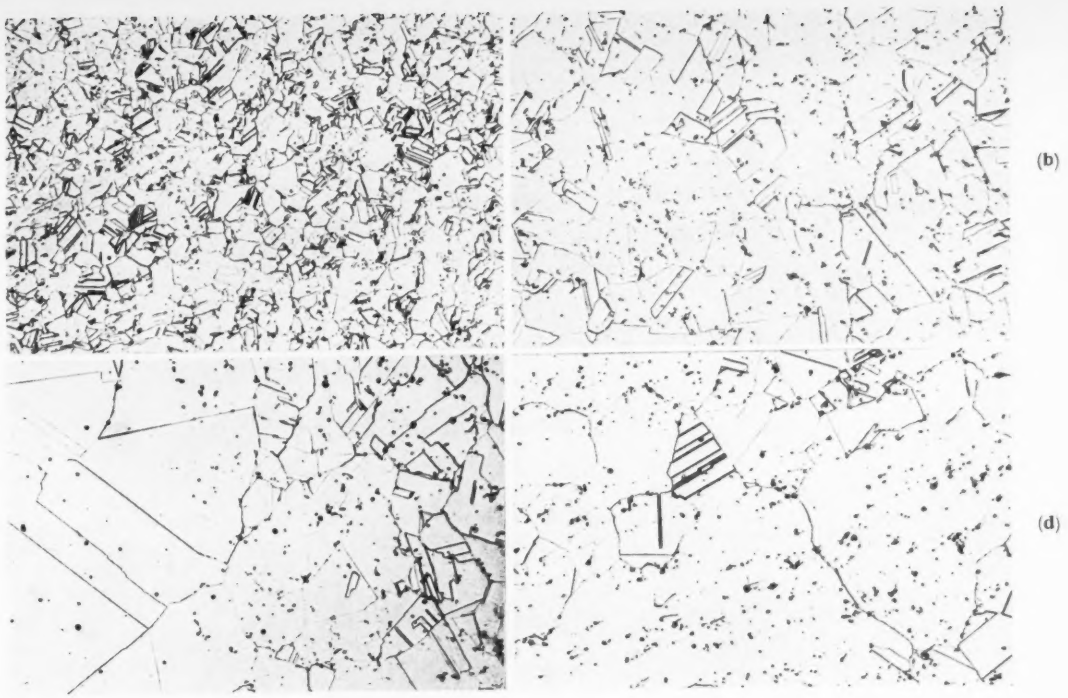

Fig. 4—Effect of solution heat-treatment temperature on structure of low-carbon N-155 alloy : (*a*) 2 hr. at 1100° C., A.C.; (*b*) 1 hr. at 1200° C., A.C. ; (*c*) 1 hr. at 1250° C., A.C. ; (*d*) 1 hr. at 1280° C., A.C. × 250

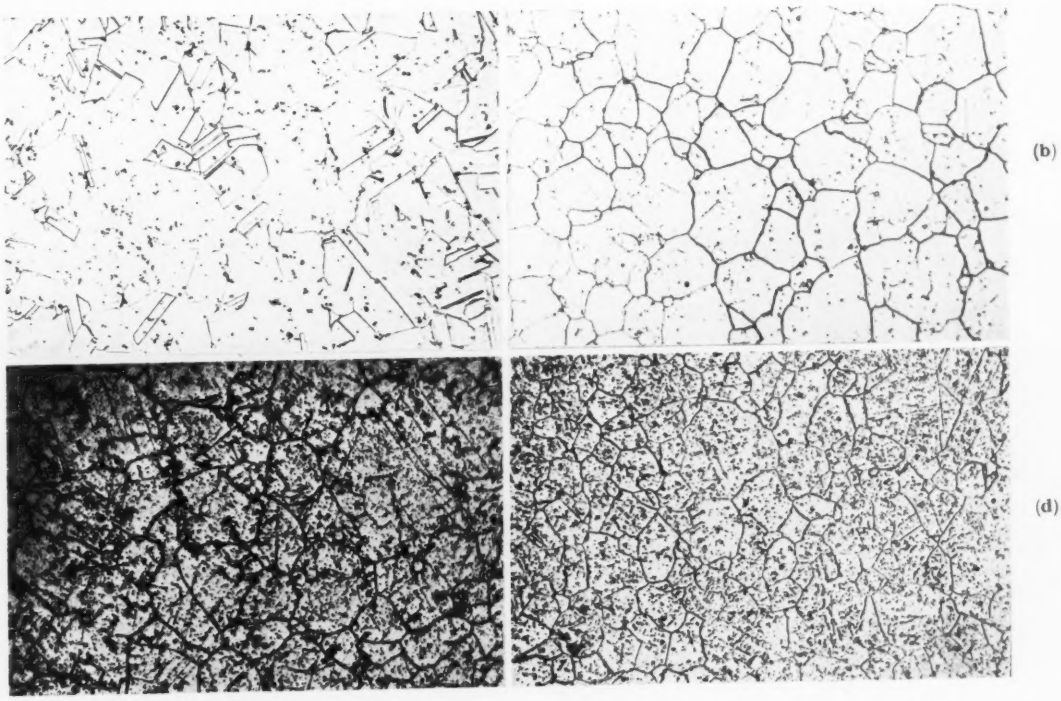

Fig. 5—Structure of low-carbon N-155 alloy after solution heat-treating for 1 hr. at 1200° C., air-cooling, and reheating for 168 hr. at various temperatures : (*a*) As solution heat-treated ; (*b*) reheated at 650° C.; (*c*) reheated at 730° C.; (*d*) reheated at 815° C. × 250

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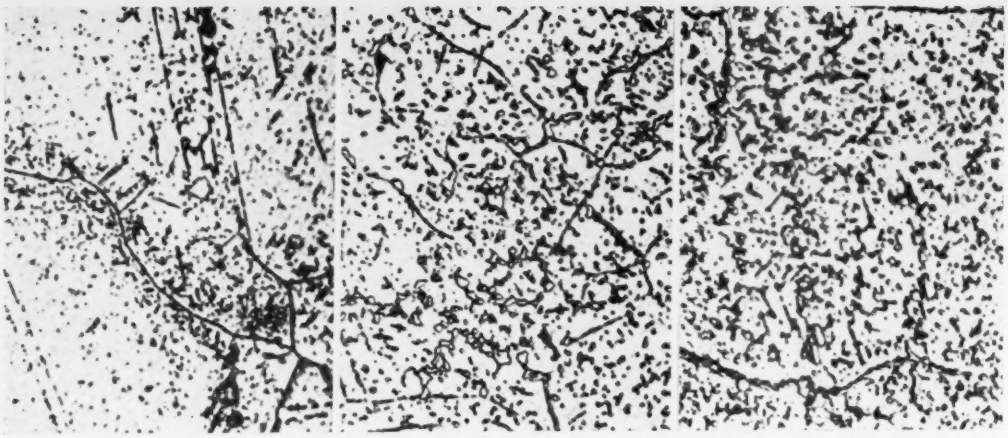
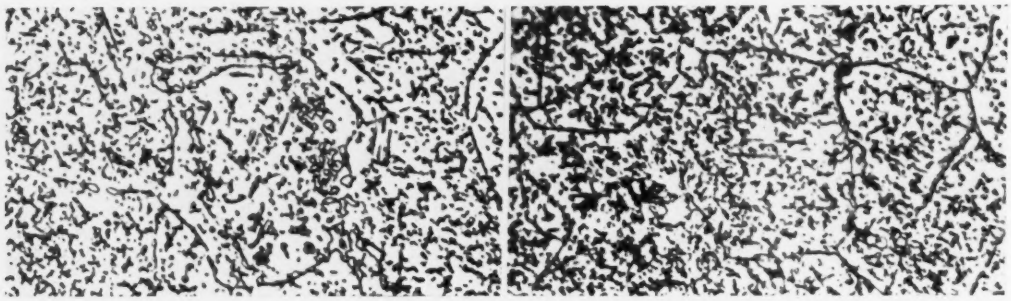


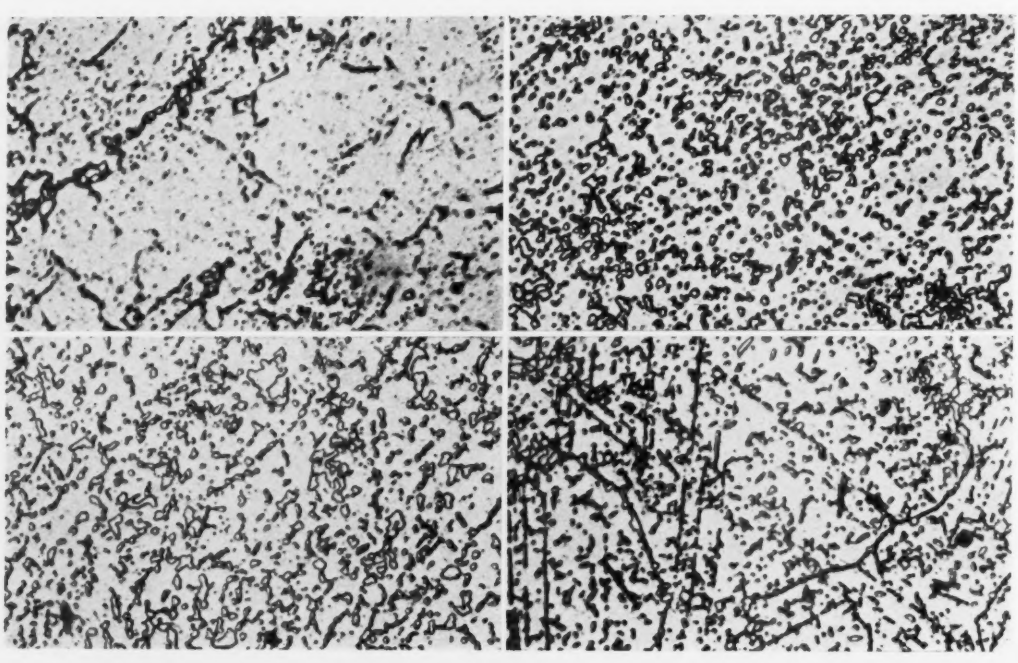
(a) (b) (c)

Fig. 6—Influence of time and stress at 815° C. on structure of low-carbon N-155 alloy, solution heat-treated 1 hr. at 1240° C., W.Q.: (*a*) 22 hr. at 11.16 tons/sq. in. stress; (*b*) 1550 hr. at 4.46 tons/sq. in. stress ; (*c*) 5500 hr. at 3.57 tons/sq. in. stress × 1000



(a) (b)

Fig. 7—As Fig. 6 but at temperature of 730° C.; (*a*) 12,000 hr. at 6.7 tons/sq. in. stress ; (*b*) 32,000 hr. at 5.58 tons/sq. in. stress × 1000



(a) (b) (c) (d)

Fig. 8—Influence of prior heat-treatment on structure of low-carbon N-155 alloy after creep testing at 815° C. and 3.57 tons/sq. in. stress: (*a*) As forged; (*b*) heated 2½ hr. at 825° C., A.C. Failed after 239 hr. with 33% elongation; (*c*) heated 1 hr. at 1000° C., A.C. Failed after 909 hr. with 18% elongation; (*d*) heated 1 hr. at 1225° C., A.C. Test discontinued after 1079 hr. with <1% elongation × 1000

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(2) The predominant phase is NbC after ageing for 12,000 hr. at 730° C., but there is evidence of the intermetallic compound M_2Nb, and the carbide Cr_4C. After 32,000 hr. at 730° C. the phases NbC, M_2Nb, and Cr_4C were identified, and the line intensities were about equal.

(3) Both NbC and Cr_4C precipitate after ageing 22 hr. at 815° C. The carbide M_6C, in addition to the carbides NbC and Cr_4C, was present after ageing for 1550 hr. After 5500 hr. the intermetallic compound M_2Nb and the carbides NbC and Cr_4C were noted, but no evidence of the carbide M_6C was found.

(4) No evidence of sigma phase was observed in the alloy after ageing at 730° or 815° C.

It will be recalled that the alloy in the strain-hardened condition is inferior in hot strength at temperatures above 650° C. to solution heat-treated metal, and that increasing the solution heat-treating temperature improves hot strength. The differences noted were attributed to an effect of microstructure, and in Fig. 8 the microstructure of samples strain-hardened and solution heat-treated at 825° and 1000° C. are shown after testing at 815° C. It is clearly seen that the precipitate in these samples has undergone appreciable coagulation, resulting in early failure as compared to the sample solution heat-treated at 1225° C.

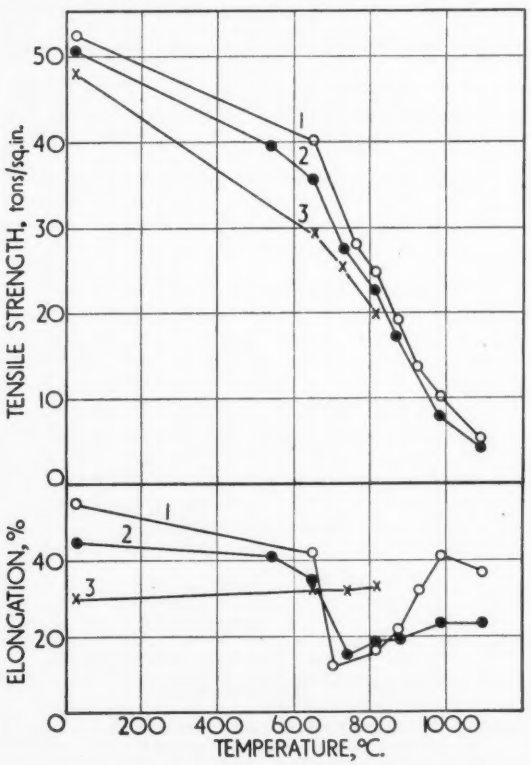
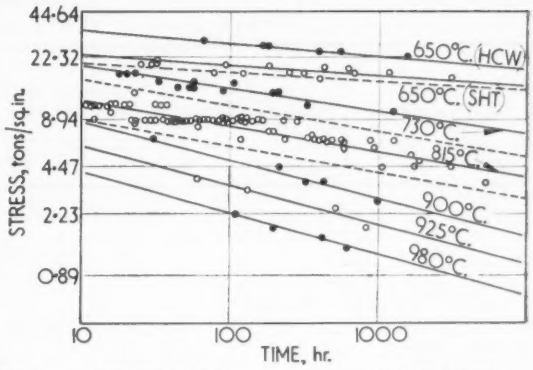


Fig. 9—Short-time tensile strength of low-carbon N-155 alloy. Curve 1: bar stock, solution heat-treated 1 hr. at 1200° C. and air-cooled. Curve 2: 0·035–0·064-in. thick sheet, commercially annealed (references 10 and 18). Curve 3: forged 14½-in. dia. × 4½-in. thick disc, 1200° C. water-quenched, 24 hr. at 730° C. and air-cooled (reference 12)



Temp.	Condition of Metal	Temp.	Condition of Metal
650° C. (HCW)	Solution heat-treated 2 hr. at 1120° C., W.Q., reduced 15% at 650–760° C. by rolling (reference 7)	815° C.	Solution heat-treated 1 hr. at 1200–1270° C. and cooled rapidly. Ageing treatments varied from none to 50 hr. at 730° and 815° C.*
650° C. (SHT)	Solution heat-treated 1–2 hr. at 1060–1230° C. and W.Q. (reference 7)	900° C.	Solution heat-treated 1 hr. at 1250° C., W.Q., heated 4 hr. at 815° C. and A.C.
730° C.	Solution heat-treated 1 hr. at 1200–1250° C. and A.C. Some specimens heated 4 hr. at 815° C. and A.C. after solution heat-treatment	925° and 980° C.	Solution heat-treated ½ hr. at 1250° C. and A.C. (reference 19)

A.C. = air-cooled
W.Q. = water-quenched

* Data compiled from tests made at the Union Carbide and Carbon Research Laboratories, Inc., and elsewhere (references 9, 12, and 13)

Fig. 10—Stress-to-rupture strength of low-carbon N-155 alloy bars

Physical Properties

For design purposes, various physical constants of the alloy are required. Table V summarizes the physical properties which have been determined, and Fig. 3 shows the variation with temperatures of Young's modulus of elasticity, modulus of rupture, and Poisson's ratio.

Mechanical Properties of Bars and Forgings

The mechanical properties of the alloy at room temperature, shown in Table VI, are typical of solution heat-treated, aged, and hot cold-worked metal. The hot cold-work values represent a relatively large disc forging made under commercial conditions.[11]

For parts operating at moderately elevated temperatures short-time tensile properties may be used for design purposes, but where creep may occur these data are not very useful, except when the service is of extremely short duration. The short-time tensile and ductility values for the alloy after heating 1 hr. at 1200° C. and air-cooling are plotted in Fig. 9, as they show the maximum stress the metal will withstand ; the variation of hot-ductility with temperature is of interest. In the solution heat-treated condition the alloy possesses relatively low ductility in the temperature range 700–870° C., but the ductility is improved by ageing for 24 hr. at 730° or 815° C.[12] It is surmised that the particle size of the precipitate has some influence on the results noted, and it appears that the precipitate which forms initially and when the alloy is under stress is more harmful to ductility than precipitates which have had an opportunity to

Table VII

CHARPY IMPACT TESTS ON LOW-CARBON N-155 ALLOY

Test Temp., ° C.	As-Solution-Heat-Treated, ° C.	Charpy Impact, ft.-lb. (Keyhole Notch)					
		650° C.		730° C.		815° C.	
		2 Hr.	168 Hr.	2 Hr.	168 Hr.	2 Hr.	168 Hr.
		Heated 2 hr. at 1100° C. and A.C.					
25	61	57	31	43	19	36	16
650	...	63	41	...	...	...	...
730	...	...	...	49	35	...	...
815	...	...	...	...	...	47	32
		Heated 1 hr. at 1200° C. and A.C.					
25	65	58	26	44	11	31	9
650	...	61	45	...	...	...	...
730	...	...	...	51	34	...	...
815	...	...	...	...	...	49	28
		Heated 1 hr. at 1250° C. and A.C.					
25	72	72	30	45	12	29	16
650	...	73	60	...	...	...	...
730	...	...	...	54	32	...	...
815	...	...	...	...	...	49	27
		Heated 1 hr. at 1280° C. and A.C.					
25	73	76	23	47	9	24	7
650	...	89	57	...	...	...	...
730	...	...	...	76	30	...	...
815	...	...	...	...	...	50	23

A.C. = air-cooled

grow somewhat without the influence of stress. As will be pointed out later, prior ageing also improves the ductility of the alloy at fracture after stress-rupture testing.

As previously mentioned, the alloy is subject to some precipitation-hardening during exposure to temperatures in the range 650–980° C., resulting in an increase in strength and hardness and a decrease in ductility and toughness at room temperature. Table VII[4] shows that the loss of toughness owing to ageing is less at elevated temperatures than at room temperature, and it is slightly greater after heat-treatment at 1280° C. than after heat-treatment at the lower temperatures, although initially the toughness is higher.

Allowable working stresses in high-temperature portions of the turbine are frequently based on rupture strength. The results of stress-rupture tests which have been carried out over the temperature range 650–980° C. on several different melts are shown in Fig. 10, where the curves are well suited for short-life designs. There is some evidence that the logarithmic rupture curve may not be linear over extended periods of time and that extended extrapolation may be misleading; extrapolation of these data to 10,000 hr. appears warranted, however, at least at temperatures below 870° C. where test data up to 32,000 hr. at 730° C. and 5500 hr. at 815° C. are available.

It was previously stated that at 650° C. optimum strength is obtained by hot cold-working the alloy after solution heat-treatment, and the top curve in Fig. 3 represents the general level of strength which can be obtained by such procedures.[7] While approximately similar results with somewhat better ductility can be obtained by hot cold-working the alloy in the as hot-worked condition (*see* Table III), this method is not generally applicable, as it does not lend itself to

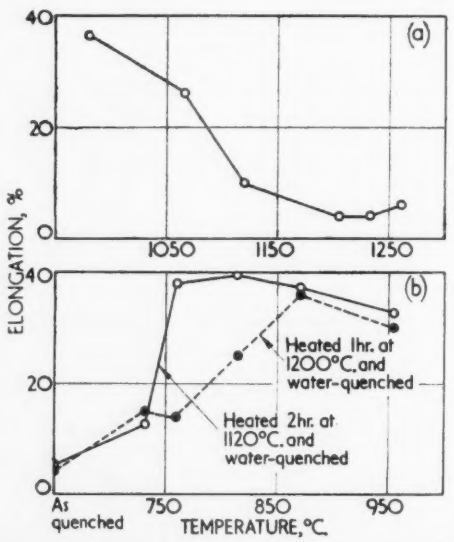


Fig. 11—(*a*) Effect of solution-heat-treating temperature on 100-hr. stress-rupture ductility at 650° C. Solution-heat-treating conditions: 980° C., 2 hr., water-quenched; 1060° C., 2 hr., water-quenched; 1120° C., 2 hr., water-quenched; 1200° C., 1 hr., water-quenched; 1230° C., ½ hr., water-quenched; 1260° C., ¼ hr., water-quenched (reference 7). (*b*) Effect of ageing for 24 hr. at various temperatures on 100-hr. stress-rupture ductility at 650° C. (reference 7)

satisfactory control and is apt to give inferior results under some conditions of hot-working.

The strength of the alloy in the solution heat-treated condition (1060–1230° C.) is somewhat lower than in the hot cold-worked condition. At 650° C. the curve for the solution heat-treated condition is based on the results of numerous tests made by Freeman and co-workers,[7] the solid line representing the approximate average curve and the dashed line indicating the minimum strength to be expected at this temperature in the solution heat-treated condition. Optimum strength was obtained in these investigations after solution heat-treating at 1120° C.; the rupture strength, however, does not vary much over the entire solution heat-treating range for this alloy.

Although not shown here, the effect of ageing at 730–815° C. after solution heat-treatment is to increase the 100-hr. life stress to about 23·22 tons/sq. in. at 650° C., but such treatments do not change the 1000-hr. life stress to any appreciable extent. While ageing imparts no great improvement in strength except at short periods of exposure, it markedly increases hot-ductility.

The curve for the 815° C. test results is shown as a band which was established from all the available data for solution-treated material. Included in the band are the tests made at the Union Carbide and Carbon Research Laboratories, Inc., in addition to those made elsewhere,[9, 12, 13] a total of nearly 100 stress-rupture tests. The solid line represents the statistical average and the shorter-dashed lines the statistical average plus or minus three times the standard deviation. The degree of scatter shown is not surprising in view of the fact that the alloys were made and heat-treated under varying conditions, and it is anticipated that less variation will exist where conditions of melting, fabrication, and heat-treatment are more uniform.

At this point it is desirable to interpolate a few remarks regarding ductility at fracture of the stress-rupture specimens. It decreases with the temperature of solution heat-treatment, but as the temperature of testing is raised the influence of the prior solution heat-treating temperature becomes less significant. The curve in Fig. 11 (*a*) shows the lowering in ductility at 650° C. owing to raising the solution heat-treating temperature.[7] The ductility of the alloy is improved after solution heat-treatment by ageing, as illustrated in Fig. 11 (*b*).[7] In Table VIII it is seen that in the aged condition the alloy exhibits good ductility at fracture over the temperature range 650–900° C. While there is a tendency for the ductility to decrease with time of exposure, as will be demonstrated later, the alloy exhibits measurable ductility even though stressed for prolonged periods.

Table VIII

DUCTILITY AT FRACTURE

Metal heated 1 hr. at 1250° C. and air-cooled, 4 hr. at 815° C. and air-cooled

Test Temp., °C.	Estimated Elongation, %	
	100 Hr.	1000 Hr.
650	20	20
730	22	22
815	28	28
900	25	20

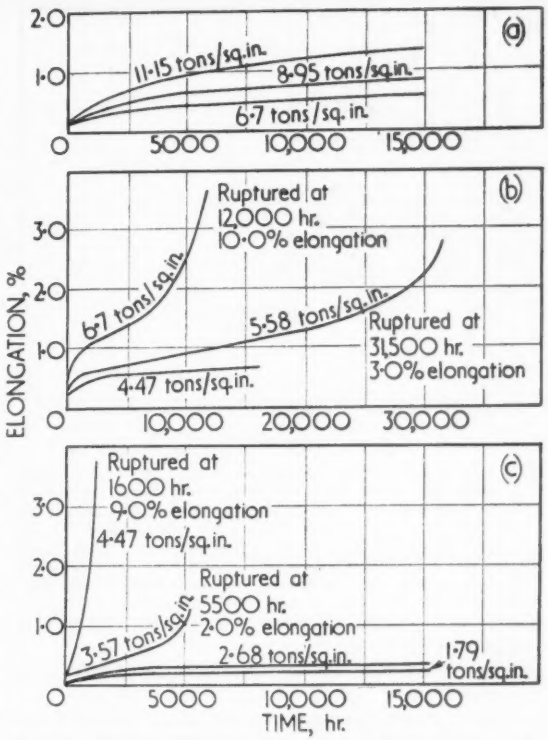


Fig. 12—Creep curves for low-carbon N-155 alloy (*a*) at 650° C. (in hot cold-worked condition), (*b*) at 730° C. (solution heat-treated 1 hr. at 1240° C. and water-quenched, heated 2 hr. at 730° C. and air-cooled) and (*c*) at 815° C. (solution heat-treated 1 hr. at 1240° C. and water-quenched, heated 2 hr. at 730° C. and air-cooled

The creep characteristics of an alloy are of importance to the designer, although the creep rate itself is not generally used to establish working stresses in short-life designs. The creep curves for various stresses at 650°, 730°, and 815° C. for periods ranging in some cases from 10,000 to 32,000 hr. are shown in Fig. 12. These curves reveal the extent of plastic deformation the alloy will undergo when stressed as a function of time, but they do not include the deformation occurring during application of the load. It is noteworthy that even after extended periods of heating under stress the alloy exhibits measurable ductility at failure. The creep rates derived from these data are given in Table IX, and the microstructure of the alloy after test is shown in Figs. 6 and 7.

Creep data become more useful when the information is plotted in the form shown in Fig. 13. The practical value of such curves lies in the fact that the working stress depends upon the operating temperature and service, and these curves permit the proper

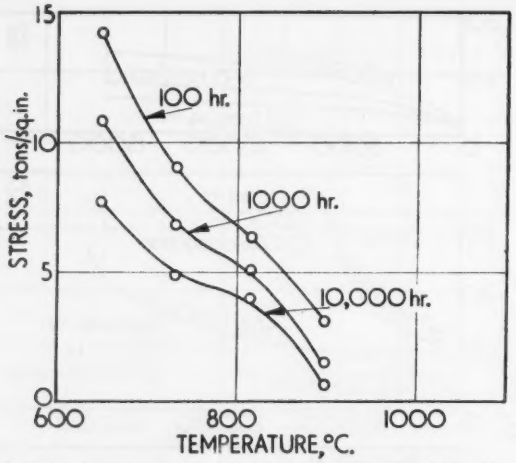


Fig. 13—Stress/temperature/time curves (1% elongation) for bars and forgings. Curves based on specimens solution heat-treated 1 hr. at 1200–1250° C., water-quenched, and reheated 4–50 hr. at 730° or 815° C. Data compiled from tests made at the Union Carbide and Carbon Research Laboratories, Inc., and elsewhere (references 9 and 12)

selection of working stress for a wide variety of temperatures.

Mechanical Properties of Low-Carbon N-155 Alloy Sheet

Many parts of jet engines are made from sheet and strip by forming and welding operations. Such assemblies frequently utilize sheet of 0·025–0·038 in. thickness, and sheets measuring 36 in. wide by 120 in. long are very often required to facilitate fabrication.

Mechanical-property data at room temperature for sheet are shown in Table X for alloys varying in carbon up to 0·35%. From the standpoint of ductility, these data show that solution heat-treatment at 1175° C. is adequate. As previously pointed out, this temperature is less detrimental to the quality of the sheet than the higher temperatures. Ageing at 760° C. lowers the elongation value, particularly after heating at 1260° C., and it markedly decreases the Erichsen values.

While the mechanical properties of the alloy in the solution heat-treated condition appear to be affected in only a minor way by variations in carbon content, the decrease in elongation across the fracture is observed clearly in the incremental-elongation curves shown in Fig. 14. However, the local bending charac-

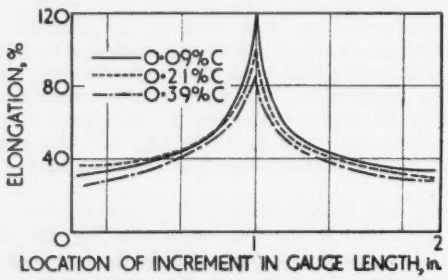


Fig. 14—Incremental-elongation curves for N-155 alloy sheet varying in carbon content

Table IX

CREEP RATE AND TOTAL DEFORMATION FOR LOW-CARBON N-155 ALLOY

For treatment of metal see Fig. 12

Test Temp., °C.	Stress, tons/sq. in.	Creep Rate and Total Deformation	Time, hr. 500	1000	3000	5000	7000	9000	11,000	13,000	15,000	20,000	25,000	30,000
650	6·70	Total deformation, %	0·23	0·28	0·35	0·42	0·47	0·50	0·53	0·56	Discontinued			
		Creep rate, %/hr.	0·00018	0·00006	0·000037	0·000037	0·000037	0·000009	0·000003	0·000003				
650	8·93	Total deformation, %	0·33	0·40	0·52	0·62	0·71	0·76	0·79	0·82	Discontinued	...	...	...
		Creep rate, %/hr.	0·00016	0·000087	0·000048	0·000048	0·000048	0·000014	0·000003	0·000003				
650	11·16	Total deformation, %	0·36	0·44	0·74	0·92	1·07	1·16	1·24	1·32	Discontinued	...	...	...
		Creep rate, %/hr.	0·00018	0·00018	0·00009	0·00009	0·000083	0·000039	0·000029	0·00003				
730	4·46	Total deformation, %	0·44	0·48	0·53	0·57	0·60	0·62	0·64	0·66	0·69	...	Discontinued	...
		Creep rate, %/hr.	0·00016	0·000017	0·000017	0·000017	0·000017	0·000003	0·000003	0·000009	0·00001	1·29	...	...
730	5·58	Total deformation, %	0·50	0·58	0·66	0·73	0·80	0·87	0·94	1·01	1·08	...	1·60	2·16
		Creep rate, %/hr.	0·00031	0·000067	0·000037	0·000037	0·000037	0·000037	0·000037	0·000037	0·000037	0·000056	0·00007	0·0002
730	6·70	Total deformation, %	0·82	0·95	1·20	1·42	1·65	2·00	3·1	Specimen ruptured				
		Creep rate, %/hr.	0·00035	0·0002	0·00012	0·00012	0·00012	0·00034						
815	1·79	Total deformation, %	0·08	0·10	0·16	0·185	0·19	0·195	0·20	0·205	0·21	...	...	...
		Creep rate, %/hr.	0·00013	0·000008	0·000008	0·000008	0·000002	0·000002	0·000002	0·000002	0·000002	...	...	...
815	2·68	Total deformation, %	0·12	0·16	0·28	0·29	0·30	0·31	0·32	0·33	0·34	...	...	...
		Creep rate, %/hr.	0·00007	0·000024	0·000024	0·000024	0·000005	0·000005	0·000005	0·000005	0·000005	...	...	...
815	3·57	Total deformation, %	0·24	0·30	0·52	1·0	Specimen ruptured							
		Creep rate, %/hr.	0·000075	0·00002	0·00014	0·00045								
815	4·46	Total deformation, %	0·85	2·0	Specimen ruptured		...	...	...	...	...	...	...	...
		Creep rate, %/hr.	0·0022	0·0045	...	...	...	...	...	...	...	...	...	...

Table X

MECHANICAL PROPERTIES OF N-155 ALLOY SHEET

Heat-Treatment	Commercial Low-Carbon				M-392 (C, 0·09%; N, 0·137%)				M-393 (C, 0·21%; N, 0·136%)				M-394 (C, 0·39%; N, 0·140%)			
	Yield Strength at 0·2% Offset, tons/sq. in.	Tensile Strength, tons/sq. in.	Elongation, %	Erichsen Ductility, mm.	Yield Strength at 0·2% Offset, tons/sq. in.	Tensile Strength, tons/sq. in.	Elongation, %	Erichsen Ductility, mm.	Yield Strength at 0·2% Offset, tons/sq. in.	Tensile Strength, tons/sq. in.	Elongation, %	Erichsen Ductility, mm.	Yield Strength, at 0·2% Offset tons/sq. in.	Tensile Strength, tons/sq. in.	Elongation, %	Erichsen Ductility, mm.
1 hr. 1175° C., A.C.	23·13	51·87	45	10·8	21·54	51·42	45	11·4	23·04	54·46	41	9·2	23·97	56·34	41	11·6
1 hr. 1200° C., A.C.	23·53	51·46	45	11·2	21·47	50·49	46	10·2	23·33	53·57	45	9·2	24·11	55·80	37	10·3
1 hr. 1230° C., A.C.	22·91	52·32	44	11·3	20·89	50·40	45	10·5	22·99	53·13	45	9·5	25·43	57·88	43	10·2
1 hr. 1260° C., A.C.	23·35	52·99	47	10·9	22·32	52·27	45	10·1	25·58	55·81	44	9·7	21·16	47·91	49	10·4
1 hr. 1285° C., A.C.	...	...	...	...	21·96	49·21	43	10·3	25·36	55·45	44	9·8	26·25	57·05	46	10·5
1 hr. 1175° C., + 16 hr. 760° C., A.C.	23·04	51·21	36	7·2	20·19	48·17	39	7·7	25·81	55·41	35	6·8	26·03	54·78	29	9·0
1 hr. 1200° C., + 16 hr. 760° C., A.C.	23·39	50·89	35	...	21·61	50·95	37	8·0	26·76	55·41	29	6·8	26·65	55·84	30	8·8
1 hr. 1230° C., + 16 hr. 760° C., A.C.	23·11	50·09	34	...	21·79	50·32	40	7·8	26·66	54·15	27	6·4	28·22	56·74	24	8·6
1 hr. 1260° C., + 16 hr. 760° C., A.C.	22·91	50·36	35	7·1	26·98	54·11	30	7·0	31·25	59·02	16	6·7	21·53	49·06	35	8·0
1 hr. 1285° C., + 16 hr. 760° C., A.C.	...	...	...	...	28·29	53·39	26	7·8	29·82	56·12	23	6·1	31·21	59·46	26	8·7

A.C. = air-cooled

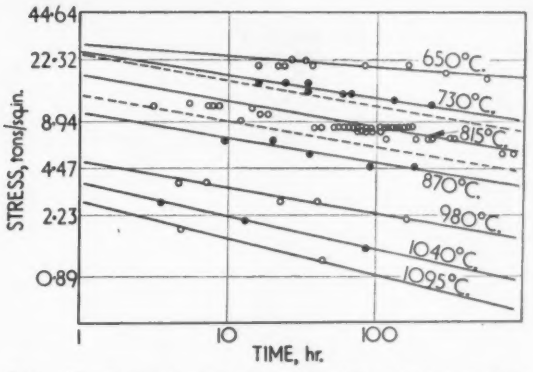


Fig. 15—Stress-to-rupture strength of low-carbon N-155 alloy sheet. Specimens 0·038–0·065 in. thick, solution heat-treated 10 min. to 1 hr. at 1120–1200° C. and air-cooled (curves for 870°, 1040°, and 1090° C. are from reference 10)

teristics of the higher-carbon alloy still exceed the minimum necessary for forming short-radius flanges, etc.

The variation of short-time tensile strength of sheet with temperature is given in Fig. 9 for comparison with bar stock. The properties of sheet do not differ significantly from those of bars.

Stress-rupture tests on sheet (Fig. 15) are of shorter duration than those for bar stock, since the use of sheet has been restricted to a great extent to short-life designs. It is of interest to note that on a short-life basis the rupture strength of sheet is practically the same as that for bars over the temperature range 650–980° C. With increase in time and temperature it would be expected that the heavier sections would show better load-carrying ability, since the percentage of cross-section affected by scaling would be smaller

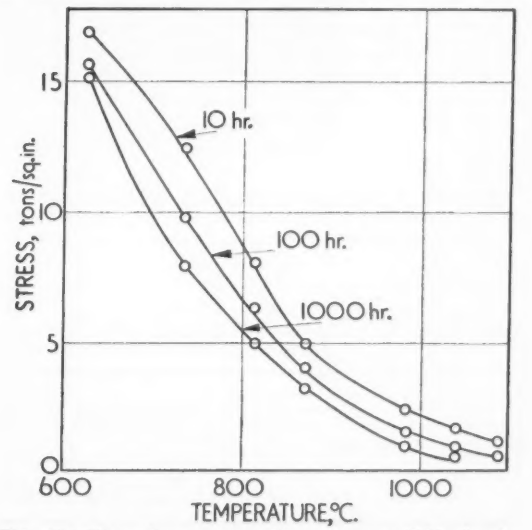


Fig. 16—Stress/temperature/time curves (1% elongation) for 0·038–0·065-in. thick sheet, based on specimens solution heat-treated at 1150–1175° C. Data compiled from tests made at the Union Carbide and Carbon Research Laboratories, Inc., and elsewhere (reference 10)

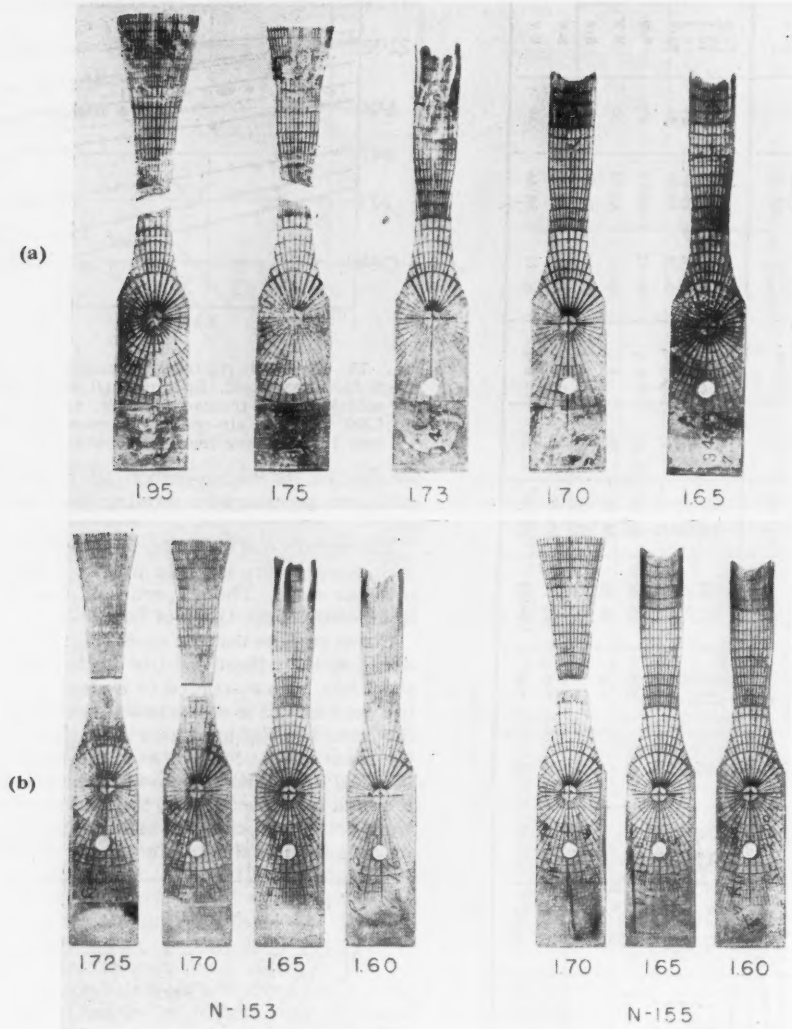


Fig. 17—Appearance of wedge-draw specimens after testing. (*a*) A.I.S.I. type 347 stainless steel heated 10 min. at 1075° C. and air-cooled. (*b*) Low-carbon N-153 and N-155 alloys heated 1 hr. at 1200° C. and air-cooled

Table XI

FORMABILITY CHARACTERISTICS OF LOW-CARBON N-155 ALLOY COMPARED WITH THOSE OF LOW-CARBON N-153 AND A.I.S.I. TYPE 347 STAINLESS STEEL

Material	Local Bending and Stretching	Stretching of Longer Gauge Lengths	Compression (Unsupported) Without Wrinkling	Drawing With Draw Ring	Erichsen Ductility
	Elongation at Failure in 0·05 in.	Elongation at Failure in 2 in.	Relative Index, E'/Fty	Limiting Ratio	Depth of Cup, mm.
A.I.S.I. type 347 stainless steel	108%	46%	8·6*	1·73	12·0
Low-carbon N-153	112%	40%	7·4*	1·65	10·8
Low-carbon N-155	103%	45%	7·9*	1·65	11·2

* Based on a shrink of 4%

Fig. 18 (*left*) — Jet tail-cone for B-45 bomber

Fig. 20 (*right*) — A steam-boiler cabin heater for the Douglas DC-3 airliner, sectioned to show condition of low-carbon N-155 alloy liner after 2107 hr. of service

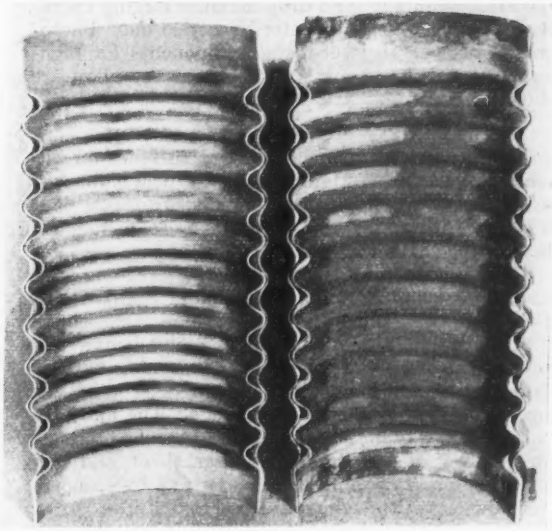


Fig. 19—Jet tail-pipe for B-45 bomber

in the case of the heavier sections. Design curves for sheet in the solution heat-treated condition are assembled in Fig. 16. Here again the stresses for a given temperature compare favourably with those for bar stock.

Formability of Low-Carbon N-155 Alloy Sheet

The foregoing shows that the alloy meets the principal requirements of a high-temperature sheet alloy, namely, good strength at elevated temperatures and adequate cold-ductility. Since the utility of a sheet alloy depends upon its ability to undergo forming operations, the alloy was subjected to several laboratory tests to evaluate its forming characteristics and to compare them with the formability of the austenitic stainless steels which are known to possess good formability.

Shanley[14] has shown that certain criteria are available which permit a comparison of the formability of different materials, namely :

(1) Percentage elongation in $\frac{1}{4}$ in. evaluates capacity for short-radius bends.

(2) Percentage elongation in 40–50 in., although 2-in. gauge lengths are indicative, reveals stretch-forming ability.

(3) Ratio of the tangent modulus at 4% elongation to the compressive yield strength is an index of shrink-forming.

(4) Ratio of the radius of the original blank to the radius of the cup after deep-drawing is an index of deep-drawing qualities.

The index of shrink, which is based on a measurement of the tangent modulus of elasticity at 4% elongation, is calculated on the assumption that tensile properties in compression are similar to those in tension, and that the ratio of the stress for any given value of strain to the yield strength of the material is a constant for materials having stress/strain diagrams roughly of the same general shape. To compress the material into the plastic range without wrinkling requires that the tangent modulus of the material corresponding to the strain developed in the forming operation remains high enough to resist buckling under the stress.

The index of deep-drawing is the limit of the ratio R/r, where R is the radius of the original blank and r is the radius of the cup after drawing. The basis of this test is the drawing of a cylindrical cup from a flat circular disc. The test was similar to that developed by Brewer and Rockwell[15] (originally devised by Sachs[16] and others), wherein a wedge-shaped specimen of sheet conforming in shape to a segment of the original disc is placed in a closely fitting tapered die and then drawn through. The distance the wedge can be drawn through the die before breaking is a measure of deep-drawability of the material, and this limit may be expressed as the R/r ratio. The appearances of wedge-draw specimens of low-carbon N-153, N-155, and type 347 stainless steel after testing are shown in Fig. 17.

In Table XI the low-carbon N-155 alloy is compared with low-carbon N-153 alloy and A.I.S.I. type 347 stainless steel on the above basis.[17] The samples of type 347 steel were heated for 10 min. at 1075° C. and air-cooled, whereas the other materials were heated for 1 hr. at 1200° C. and air-cooled before testing. On the basis of these tests it may be said that the formability of low-carbon N-155 alloy is comparable with that of A.I.S.I. type 347 stainless steel, although power requirements will be greater owing to its higher strength. These laboratory data have been confirmed in production, as deep-drawing,

spinning, stamping, and drop-hammer forging operations have all been satisfactorily carried out. Photographs of several sheet-metal components for high-temperature service constructed from the alloy are shown in Figs. 18 to 20.

SUMMARY

The war-time development of gas turbines for aircraft propulsion has stimulated a great deal of interest in alloys for service in the temperature range 650–980° C. Alloys for this purpose must have good fabricating characteristics.

It is concluded on the basis of the foregoing tests that low-carbon N-155 alloy (nominal composition : Carbon 0·12%, nickel 20%, chromium 20%, cobalt 20%, tungsten 2%, niobium 1%, molybdenum 3%, nitrogen 0·12%, and the remainder iron) is particularly suited for highly stressed parts required for operation in this temperature range. The alloy has a high degree of hot-workability and can be produced in the form of bars, forgings, plates, sheet, and strip of good quality, and in sizes adaptive to economic fabrication. Although it is strong and stiff, it can be formed by bending, spinning, stamping, and drawing. It possesses useful creep, stress-rupture, and impact strength at elevated temperatures, and because of its high chromium content there is considerable assurance that it will satisfactorily resist oxidizing atmospheres. To take advantage of its properties, however, close consideration must be given to its metallurgical characteristics, and while certain procedures have been found to give best results they may be modified as indicated, in order to satisfy specific conditions of service

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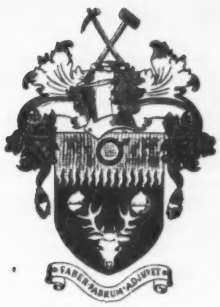
PROCEEDINGS OF THE INSTITUTE



REPORTS OF COUNCIL - OFFICIAL NOTICES

ANNUAL GENERAL MEETING, 1950

The EIGHTY-FIRST ANNUAL GENERAL MEETING OF THE IRON AND STEEL INSTITUTE was held in London on Wednesday and Thursday, 26th and 27th April, 1950, at the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1. Sir ANDREW MCCANCE, LL.D., D.Sc., F.R.S., the Retiring President, occupied the Chair for the first part of the first session, his place thereafter being taken by Mr. J. R. MENZIES-WILSON, O.B.E., the new President.

Sessions were held at 10 A.M. and 2.30 P.M. on both days, a Buffet Luncheon being provided each day in the Library of the Institute. On the Thursday evening a Members' Dinner was held at the Dorchester Hotel, Park Lane.

The minutes of the previous Meeting were taken as read and signed.

PRESENTATION OF REPORT OF COUNCIL AND STATEMENT OF ACCOUNTS FOR 1949

The **President** (Sir Andrew McCance, LL.D., D.Sc., F.R.S.): I wish to extend a cordial welcome to all the members present and to the many guests from foreign countries.

I have to present for your approval the Report of Council on the work of the Institute in 1949; this was published in the April issue of the *Journal*. During recent years the number of members of the Institute has steadily increased, so that at the end of December last the total was 92% above the low-water mark of 1941. A year ago I indicated that we thought that we were approaching the top of the curve, and this has proved to be correct. The total at the end of the year under review was almost exactly the same as the total for the year before, *i.e.*, 4909 against 4903. There is always a falling off at the beginning of the year, and the present total, after taking into account the elections which will be put before you later this morning, will be about 4780. We must try to make good the deficiency during the coming year. Although we may more or less have reached saturation point in this country, there should still be a fruitful field for expansion overseas, and I would ask members with contacts in other countries to bring to the notice of their friends the advantages of membership.

The chief of these is undoubtedly the receipt of our monthly *Journal*, which is being published as usual. In spite of the high cost of publishing, we are planning a very small increase in the size this year. The favourable comments which we continue to receive confirm us in our view that the quality of the contents is being maintained. This is a matter to which the Council attach great importance, and it may be necessary to take steps to ensure that a higher standard is reached, both because an Institute such as this should aim at publishing only the best, and because the volume of material submitted for publication is increasing. I would emphasize the great necessity for brevity in the papers that are submitted.

During the year we published three Special Reports and a comprehensive Bibliography on the Rolling of Iron and Steel. We also continued to supply translations of important foreign papers.

I have on previous occasions referred fully to the changes in the Bye-laws, so that it is not necessary to enlarge on this. The various changes came into effect on 1st January, 1950.

Our Annual and Autumn Meetings were held in London, and there were one or two other meetings on special subjects. The Engineers Group continues to hold successful meetings. In this connection, I wish to refer particularly to Mr. Cartwright. He has been Chairman of the Group since its inception, and its success is largely due to his enthusiasm and knowledge. His period of office has come to an end, and I want to record our thanks to him, and also to his colleagues on the Committee. (*Applause.*) You will be glad to learn that Mr. Williams, of the Park Gate Company, has agreed to become Chairman of the Group. We wish him every success in carrying on this work. (*Applause.*)

The Council are pleased to record the continuance of very friendly relations with a number of other organizations. I wish to refer especially to the British Iron and Steel Research Association, the Institute of Metals, and the affiliated Local Societies. The presence of numerous representatives of foreign Societies, to which I have already referred, is a matter of very great satisfaction to us.

I do not think that other activities call for special comment. They are referred to in the Report which is before you.

I beg to move that the Annual Report of Council and the Accounts for 1949 be adopted, and I will ask Mr. James Mitchell, the Honorary Treasurer, to second the resolution.

The **Honorary Treasurer** (Mr. James Mitchell, C.B.E.): The one outstanding fact about the Accounts this year is that our income has been greater than our expenditure; there is a balance, as you will see from the Report, of over £1800. That in itself is some cause for satisfaction, but it is no cause for complacency. If you examine the Accounts carefully, you will see that, in spite of increased subscriptions, we are depending on advertisement revenue to keep ourselves more or less solvent. The purists do not like the advertisements in the *Journal*; at the moment either they can have them or they can have no *Journal* at all.

There is no other point that I want to emphasize, except that I support what the President has said: let us all see that we do what we can to maintain the standard of membership. My duty is to point out, from a purely mercenary point of view, that four guineas is four guineas as far as the Institute is concerned, but one might point out to individuals and to companies that it is a good bargain.

The motion was carried unanimously.

AWARD OF THE BESSEMER GOLD MEDAL FOR 1950 TO MR. JAMES MITCHELL, C.B.E.

The **President**: The award for 1950 of our highest honour, the Bessemer Medal, is, by the unanimous decision of the Council, to be made to Mr. James Mitchell. The association of Mr. Mitchell with the iron and steel industry commenced very early; in fact, almost immediately after he had completed his training at the Royal Technical College in Glasgow. Since then he has been actively engaged in the tube section of the industry, and to most of us he will always be associated in our minds with the revival in this country of basic Bessemer steelmaking from pig iron made from home ores. When Stewarts and Lloyds decided to transfer their main steelmaking activities to Corby, they took a step which required great courage and foresight. Those of us who have had anything to do with the starting of new works can appreciate the tremendous amount of work and responsibility which was involved in an undertaking of that kind. It required not only great technical knowledge but qualities of decision and determination quite above the average. In that work Mr. Mitchell has taken a major share, and so the honour which has been given to him by the Council is one which is extremely well deserved.

It is also a matter of great personal pleasure to me that one of my last duties in this office of President should be to present this award to Mr. Mitchell, for I have enjoyed his personal friendship for many years. It gives me the greatest pleasure, therefore, to hand the Bessemer Medal to Mr. Mitchell.

The President then, amid applause, made the presentation.

Mr. **James Mitchell**, in reply, said: There is no one in the industry, Sir Andrew, from whom I could receive this token of a great honour with such satisfaction as from yourself. You have referred to our long-standing friendship, and I feel that the warmth of your words has been affected by that; but there is enough of the Scot in me to take a discount for this, and even then there is a very reasonable amount of over-praise left.

Recollection of these ceremonies, and research into the *Journal*, has made me realize that the theme of my remarks should be those who have helped me in the past, with a slight reminiscent nostalgia for the good old days. I have not time to give a list of those who have helped me: they have been very many. And, in spite of my long connection with the industry, I shall not make any nostalgic reminiscences.

I would, however, like to say that I have been a very fortunate individual, at least in two specific ways. One is that from the beginning of my life I have been able to follow the path that I wanted to follow, and to do the work that I wanted to do and in which I have been intensely interested. I have had a great deal of personal pleasure from this, which is one of the reasons I have been able to do anything useful. The other great gift of fortune to me was that she directed my steps towards the great company that I have been with for forty years. With a far-seeing board, plenty of facilities, and lots of chances of showing results, that was opportunity with a large O. In that company, too, I found so many colleagues and friends that any little success I have had is really theirs, and not mine. It has been very much a joint effort.

One of my friends, himself a Bessemer Medallist, said he was very pleased to know that this time the Council had given the Medal to someone who was still in service. That is a challenge and an opportunity; a challenge to do something to live up to what the President has said, and an opportunity to help the industry, in so doing.

THE SIR ROBERT HADFIELD MEDAL

The **President**: I have pleasure in announcing the award by the Council of the Sir Robert Hadfield Medal this year to Mr. G. D. Elliot, of the Appleby-Frodingham Steel Company, for his contributions in practice and theory to the development of blast-furnace operation. Mr. Elliot is known to us all, and the Appleby-Frodingham works and their practice have been a standard of reference for blast-furnace operators all over the country. It is therefore with very great pleasure that I present the certificate of this award to Mr. Elliot. Owing to the die of the medal having been broken when stamping it, the medal is not available, but will be sent on to him later.

The President then, amid applause, made the presentation.

THE CARNEGIE SILVER MEDAL FOR 1949

The **President**: The Carnegie Silver Medal for 1949 has been awarded to Mr. N. H. Polakowski, for his paper on "*The Compression Test in Relation to Cold Rolling.*"

The President then, amid applause, made the presentation.

THE WILLIAMS PRIZE FOR 1949

The **President**: The Williams Prize for 1949 has been awarded jointly to Dr. D. F. Marshall and Mr. H. C. White, of the Park Gate Iron and Steel Company, for their paper on "*The Conversion to Oil Firing of the Open-Hearth Furnaces at Park Gate Works.*"

The President then, amid applause, made the presentations.

THE ABLETT PRIZE FOR 1949

The **President**: The Ablett Prize for 1949 is also a joint award, to Mr. E. L. Diamond and Mr. A. M. Frankau, for their paper on "*Present Methods of Open-Hearth Furnace Charging.*"

The President then, amid applause, made the presentations.

CHANGES ON THE COUNCIL

The **Secretary** (Mr. K. Headlam-Morley): I have to announce the following changes on the Council

since the last General Meeting, in November, 1949:

New Honorary Members of Council—The following are Honorary Members of Council during their periods of office:

Mr. H. S. Tasker, President of the Institute of Metals, in place of Sir Arthur Smout.

Professor H. W. Swift, M.A., D.Sc., President of the Sheffield Society of Engineers and Metallurgists, in place of Mr. B. W. Doncaster.

Dr. J. White, President of the Sheffield Metallurgical Association, in place of Mr. A. Roebuck.

Mr. E. J. Heeley, President of the Manchester Metallurgical Society, in place of Dr. D. Binnie.

Dr. S. J. Kennett, President of the Liverpool Metallurgical Society.

Mr. C. H. T. Williams, Chairman of the Engineers Group.

In accordance with Bye-law 10 the names of the following Vice-Presidents and Members of Council were announced at the Autumn Meeting, 1949, as being due to retire at the present Annual Meeting:

Vice-Presidents—Mr. W. B. Baxter, Mr. H. H. Burton, and Mr. R. Mather.

Members of Council—Professor J. H. Andrew, Mr. N. H. Rollason, Mr. R. A. Hacking, Mr. D. F. Campbell, and Mr. I. F. L. Elliot.

No other members having been nominated up to one month previous to the present meeting, the retiring Vice-Presidents and Members of Council are now presented for re-election.

The **President**: I declare them duly re-elected.

ANDREW CARNEGIE SCHOLARSHIPS

The **Secretary**: Since the last General Meeting, the following awards of Andrew Carnegie Scholarships have been made: To Mr. E. T. Turkdogan (Sheffield University), for a study on the effect of sodium oxide additions to steelmaking slags, and to Mr. P. L. Chang (Sheffield University) for a study of hydrogen diffusion in steel at elevated temperatures.

FUTURE MEETINGS

The **Secretary**: The following meetings have been arranged for this year:

A Special Meeting will be held in Glasgow from 12th to 15th September, 1950. The programme will be announced before the end of May.

A Symposium on High-Temperature Steels and Alloys for Gas Turbines will be held in London on 18th and 19th October, 1950. In connection with this, Air Commodore Sir Frank Whittle, K.B.E., C.B., will give the Fifth Hatfield Memorial Lecture, on "The Development of the Gas Turbine and the Need for Special Steels and Alloys," on 17th October, 1950.

The Autumn General Meeting will be held in London on 15th and 16th November, 1950.

MESSAGE FROM THE PRESIDENT OF THE AMERICAN IRON AND STEEL INSTITUTE

The **President**: I have just received a telegram which I am sure will interest you. It is from Mr. Walter S. Tower, President of the American Iron and Steel Institute:

> "Cordial greetings on the occasion of your Annual General Meeting and congratulations to the men from the industry who have such an excellent performance to their credit, with best wishes for a successful meeting."

We shall all be pleased by this very happy gesture on the part of our American associates. (*Applause.*)

BALLOT FOR THE ELECTION OF MEMBERS

Mr. **R. Wilcock** (Sheffield) and Mr. **H. Allsop** (Sheffield), who were appointed scrutineers of the ballot, reported that the following candidates had been duly elected:

Members

Andrews, James (Motherwell); **Antelo,** Héctor F. (Buenos Aires, Argentina); **Austin,** Chester R., B.Cer.Eng., M.Sc., F.A.Cer.S. (Pittsburgh, Pa., U.S.A.); **Ayala,** Urbano Lopez (Mexico); **Beck,** Paul A., M.E., M.S. (Notre Dame, Indiana, U.S.A.); **Bell,** Douglas Irving, L.I.M. (Sheffield); **Bhaduri,** Sukumar, B.Sc., B.Met. (Calcutta, India); **Bichler,** Antonin, B.Sc.(Met.) (Trinec, Czechoslovakia); **Bidgood,** Ivor Michael, M.Sc. (Neath, Glam.); **Bock,** W. Kenneth, Ph.D., M.S. (Cleveland, Ohio, U.S.A.); **Boogaerdt,** M. (Ymuiden, Holland); **Bouchaud,** Peter A. (Hayange, Moselle, France); **Burn,** Alan Hall, L.I.M. (Middlesbrough); **Camolese,** Guido, Dipl. Ing. (Milan, Italy); **Chapman,** Richard D., M.S. (Detroit, Michigan, U.S.A.); **Colinese,** Philip Ernest, B.Sc. (London); **Colmant,** Raymond (Hayange, Moselle, France); **Cottell,** George Arthur, M.Sc., A.I.M. (Manchester); **Crapper,** Alwyn L. (Sheffield); **Dasgupta,** Dhruba Ranjan, B.Sc. (Calcutta, India); **de Nardo,** *Dr.* Juan Bautista (La Plata, Argentina); **Dherse,** Louis (Paris, France); **Dodd,** James (Scunthorpe, Lincs.); **Doshi,** Maganlal S., B.Sc.(Eng.) (Burnpur, West Bengal, India); **Dowding,** Michael Frederick, M.A., A.M.I. Mech.E. (Sheffield); **Ekelund,** Bror Sune (London); **Fairfield,** Peter Lawson, B.Sc.(Tech.), Grad.M.I.E.E. (Manchester); **Ferguson,** William H., B.Met.E. (New York, U.S.A.); **Fodor,** Gabriel (Rueil-Malmaison, France); **France,** Cyril (Scunthorpe, Lincs.); **Gardner,** Robert Nathan Henry, B.Sc. (Birmingham); **Gibson,** George, B.Eng. (Scunthorpe, Lincs.); **Golcher,** William Ernest (Wednesbury, Staffs.); **Gregg,** James L., B.S.Met.Eng. (Ithaca, N.Y., U.S.A.); **Groocock,** John Henry (Port Talbot, Glam.); **Guillan,** *Lt.-Col.* S. C., T.D. (London); **Hague,** Allen (Sheffield); **Hanson,** Frederick W., B.S. (New York, U.S.A.); **Hentz,** Ake G. (Stockholm, Sweden); **Heusser,** Max H. (Winterthur, Switzerland); **Houseman,** Bernard Gilpin (Newcastle-upon-Tyne); **Hudson,** Robert Frederick, B.Met.E. (Melbourne, Australia); **Hughes,** Charles Robert William (Buenos Aires, Argentina); **Hunter,** Guy Harry (Sheffield); **Huntley,** John Holding (Glasgow); **Johansson,** Klas-Erik (Hagfors, Sweden); **Killander,** Sten Axel (Bofors, Sweden); **Killingworth,** Donald, B.Sc., F.I.M. (Lincoln); **Kimball Leach,** W. (Ontario, Canada); **Kuo,** Ke-hsin, B.Sc. (Stockholm, Sweden); **László,** *Dr. Ing.* Franz Michael (Melbourne, Australia); **Lee,** Morgan Hamilton (Swansea); **Lister,** Thomas Stott, B.Sc., A.I.M. (Birmingham); **Lythall,** Reginald Tarlton, M.I.E.E. (London); **McConnell,** Alex McD., A.R.I.C., L.I.M. (Manchester); **Magnuson,** Helge (Eskilstuna, Sweden); **Meyerhofer,** Ernst A. (Zurich, Switzerland); **Michael,** Anthony Dennis, B.Sc.Eng. (Met.) (London); **Miller,** Jack Robert, B.S. (New York, U.S.A.); **Modin,** Sten Olof (Stockholm, Sweden); **Molinder,** Anders Göran, S.M. (Munkfors, Sweden); **Nolan,** Vincent J., B.S. (New York, U.S.A.); **Norén,** Tore (Gothenburg, Sweden); **Osborn,** Frederick M. (Sheffield); **Packham,** Peter Charles, B.Sc.Eng.(Met.) (Sheffield); **Paish,** Ralph, L.I.M. (Gloucester); **Parr,** Frank Edmeston (London); **Pearson,** John, Ph.D., M.Sc. (London); **Phailbus,** Theodore, B.Sc.Eng.(Mech.) (Lahore, Pakistan); **Phillipson,** George Arnold, F.Inst.F. (Ebbw Vale); **Price,** Alexander Bernard, A.M.I.Mech.E. (Erith, Kent); **Pugh,** Alfred Edward, A.I.M. (Wolverhampton); **Pyke,** Brian R. (Hereford); **Rapatz,** *Prof. Dr. Ing.* Franz (Kapfenberg, Austria); **Richards,** William Gwynfab, B.Sc. (Sunbury-on-Thames, Middx.); **Rybczynski,** Ludwik (Poznan, Poland); **Sandon,** Edward G., Dipl.Ing. (Bilbao, Spain); **Schaub,** Cyril (Fagersta, Sweden); **Schlumpf,** Robert W. (Houston, Texas, U.S.A.); **Schrero,** Morris (Pittsburgh, Pa., U.S.A.); **Siddiqi,** Rafir Ahmad, B.Sc. (Karachi, Pakistan); **Tweeddale,** James George, A.M.I.Mech.E. (London); **Varoquaux,** Jean Arthur (Villerupt, France); **Vaughan,** Charles Stanley, L.I.M. (Deepfields, Staffs.); **Wing,** Peter Denniff A.Met., A.I.M. (Chesterfield); **Yates,** Harry (Glasgow).

Associates

Banerjee, Bani R., B.Met., M.Eng. (Chicago, U.S.A.); **Beton,** Robin Hartley (Manchester); **Bhargava,** Ram Dey (Banaras, India); **Bhat,** Uppinangady Gopalkrishna (Bombay, India); **Bunshah,** Rointan Framroze, B.Sc.(Met.) (Pitts-

burgh, Pa., U.S.A.); **Cartmell,** Leo John (London); **Chang,** Wen-Hsiang, B.S. (Rolla, Missouri, U.S.A.); **Chatterjee,** Asit Kumar, B.Sc., B.Met. (Howrah, India); **Chaudhuri,** Arup Ratan, B.Sc. (Manchester); **Chilton,** John P. (Cambridge); **Conder,** Peter (London); **Crank,** Bernard Frederick, B.Sc., G.I.Mech.E., A.M.C.T. (Sheffield); **Davies,** Brian Gowan, B.Sc. (Cardiff); **Dennis,** Thomas John (Birmingham); **Donaldson,** John William (London); **Elliott,** Ronald (Leeds); **Fleming,** Graham (London); **Hall,** John Richard (London); **Harbord,** Reginald John (London); **Harris,** Louis Reuben, B.A. (Avonmouth, Bristol); **Hellon,** Alwyne Lancelot (Middlesbrough); **Heslop,** John (Leeds); **Hugo,** Jacques Pierre, B.Sc.(Eng.) (Sheffield); **Jessop,** Alan Fields (Birmingham); **Johannsson,** Thor (Middlesbrough); **Kenaghan,** Francis John (Birmingham); **Kula,** Eric Bertil, S.B. (Stockholm, Sweden); **Laker,** William Eric, B.Sc. (Bristol); **Lappin,** Robert Lawrence (Middlesbrough); **Leys,** James Alexander, B.Sc. (London); **Light,** William Thomas (Gowerton, Glam.); **Lilly,** Gordon Fraser, B.Sc. (Corby, Northants.); **Long,** Reginald Lionel, B.Sc. (Rotherham, Yorks.); **Lund,** Frederick John (Sheffield); **Mackay,** James Matthew (London); **McLean,** John Scott, B.Sc. (Coatbridge, Lanarkshire); **Marwaha,** Jagdish (Banaras, India); **Morris,** Kenneth Arthur (Bilston, Staffs.); **Nichani,** Madan Lal (Banaras, India); **Nygren,** Erik (Munkfors, Sweden); **Olds,** Geoffrey Charles Edward, B.Sc. (Rugby); **Palmer,** Arthur Robert (London); **Peacock,** Thomas Edward (Newcastle); **Pell,** Frederick Roy (Luton, Beds.); **Pile,** Bryan Harold (London); **Porter,** John M. (Leeds); **Potter,** Pat (London); **Preston,** Derek (Sheffield); **Ridley,** Norman (Newcastle-upon-Tyne); **Samuel,** Philip, B.Met. (Sheffield); **Sarkar,** Ananda Dulal, B.Sc. (Bihar, India); **Scarrott,** Derrick Ronald (Glasgow); **Scholes,** Peter Haydock (Sheffield); **Shapton,** Royston Walter (London); **Smallman,** Raymond Edward (Birmingham); **Spray,** Charles Alan Francis Thomas (London); **Strong,** Geoffrey Victor (London); **Sutherland,** John McKellar (Chesterfield); **Tandon,** Prem Parkash, B.A. (Banaras, India); **Wainhouse,** Donovan Michael (Leeds); **Waller,** Kenneth (Glasgow).

The **President**: I declare the candidates duly elected. They number 147, and bring the total membership of the Institute to 4784.

INDUCTION OF THE PRESIDENT-ELECT, MR. J. R. MENZIES-WILSON, O.B.E.

Sir **Andrew McCance**: I now come to my last duty as President, and that is to introduce the new President, Mr. Menzies-Wilson. Mr. Menzies-Wilson has been associated with the iron and steel industry for a very long time, not only directly but through his father, and I believe through his grandfather as well. His association with Stewarts and Lloyds is well known, and at the present time he occupies the very responsible position of Managing Director of that large and successful concern. His selection continues the very close association of the Institute with the practical and manufacturing side of the industry, and no better selection could have been made. It gives me very great pleasure, therefore, to invite Mr. Menzies-Wilson to occupy the President's Chair.

Sir Andrew McCance then vacated the Chair and inducted into it, amid applause, the new President, Mr. J. R. Menzies-Wilson, O.B.E.

The **President** (Mr. Menzies-Wilson): I appreciate very much the honour done to me in electing me your President for this year. I am very conscious that I am following in the footsteps of a great man, and I am doubtful whether I can emulate his efforts.

VOTE OF THANKS TO THE RETIRING PRESIDENT

The **President** (Mr. Menzies-Wilson): My first duty is to propose, on your behalf, a very sincere vote of thanks to our immediate Past-President, Sir Andrew McCance. Sir Andrew has been President for two years. When he came into the Chair, one of his main objects was to try to get the Institute on to a sound financial basis. You have heard from Mr. Mitchell how successful his efforts have been. They are two Scots, and that may have had something to do with it. I feel a great responsibility in keeping that position where it is, but I have no doubt that with Mr. Mitchell's able help we shall manage, or at least we shall try very hard.

I ask you to accord to Sir Andrew a very hearty vote of thanks for the work that he has done for the Institute and for the results that he has achieved.

The vote of thanks was carried unanimously, with acclamation.

Sir **Andrew McCance**: I thank you very sincerely for your response to the very kind references made by the President to myself.

PRESENTATION OF THE PRESIDENTIAL ADDRESS

The **President** (Mr. Menzies-Wilson, O.B.E.) then delivered his Presidential Address. The text of the Address will be found on pp. 129–137 of the June, 1950, issue of the *Journal*.

VOTE OF THANKS TO THE PRESIDENT FOR HIS ADDRESS

Sir **Andrew McCance**: The subject which the President has chosen for his Address is one of very timely interest and one on which he is an acknowledged expert. Owing to the very great increase in the production of iron and steel all over the world, the problem of iron ore supplies is becoming a matter of serious concern. In America, I think it is agreed that the Mesabi ore, on which the Americans have depended almost entirely during the past fifty years, is at any rate approaching exhaustion; for all practical purposes, in 20 years or so it will no longer be a main source of supply. The Americans, like ourselves, are constantly looking for new sources of supply, and, as the President has emphasized, these are being found in more inaccessible parts of the world, with a consequent great increase in cost, particularly for transport.

The subject is one of very live interest. So far as this country is concerned, it is a great satisfaction to learn that the reserves are very substantial. They may be low grade, but they are likely to last for a considerable length of time, and the method of winning them is being tackled with great technical imagination and determination. The President's Address, therefore, will be a most interesting addition to our records, and I ask you to accord him our warmest thanks.

The vote of thanks was carried unanimously, with acclamation.

PRESENTATION OF PAPERS

The following papers were presented and discussed (the dates of publication are given in parenthesis):

Wednesday, 26th April

Morning Session

"Characteristics of Scrap in Relation to Bulk Handling," by E. L. Diamond (*April*, 1950).

Afternoon Session

Joint discussion on

"The Overheating and Burning of Steel. Part III—The Influence of Excessive Reheating Temperatures on the Mechanical Properties and the Structure of Alloy Steels," by A. Preece, J. Nutting, and A. Hartley (*January*, 1950).

"The Detection of Overheating and Burning in Steel by Microscopical Methods," by A. Preece and J. Nutting (*January*, 1950).

"Grain-Boundary Phenomena in Severely Heated Steel," by T. Ko and D. Hanson (*January*, 1950).

"A Note on the Overheating of Steel," by E. C. Rollason and D. F. T. Roberts (*April*, 1950).

"The Extension of the Ar_1 Range with Carbide Formation in Mild Steel due to High-Temperature Treatment," by J. H. Whiteley (*April*, 1950).

Thursday, 27th April

Morning Session

"The Influence of Low Percentages of Certain Elements on the Microstructure of Pure Iron–Carbon Alloys and Cast Irons," by W. J. Williams (*April*, 1950).

Joint discussion on

"The Thermodynamic Background of Iron and Steel Making Processes. I—The Blast-Furnace," by F. D. Richardson and J. H. E. Jeffes (*December*, 1949).

"The Influence of Gas/Solid Temperature Differences on Blast-Furnace Operation," by J. Taylor (*February*, 1950).

Afternoon Session

Joint discussion on

"Blast-Furnace Gas Cleaning. An Analysis of Plant Performance," by R. F. Jennings (*March*, 1950).

"Blast-Furnace Gas Cleaning. Methods for Calculating the Motions of Particles in a Gas," by J. Stringer (*March*, 1950).

Joint discussion on

"Proposals for the Modification of a Blast-Furnace Top to give Controlled Burden Distribution," by E. L. Diamond (*February*, 1950).

"A New Blast-Furnace Stock-Rod Gas Seal," by E. J. Walklate (*December*, 1949).

On the motion of the President, a vote of thanks was accorded by acclamation to the authors of the papers presented at the Meeting.

The discussions on these papers will be published in the April issue of the *Journal*.

MEMBERS' DINNER

A Dinner was held at the Dorchester Hotel, Park Lane, London, W.1, on Thursday, 27th April, 1950. Mr. J. R. Menzies-Wilson, O.B.E., President of the Institute, was in the Chair, and about six hundred members and guests were present. The guests included His Excellency A. J. Clasen (Luxemburg Minister), Field Marshal Sir William J. Slim, G.B.E., K.C.B., D.S.O., M.C. (Chief of the Imperial General Staff), General Sir James Steele, K.C.B., K.B.E., D.S.O., M.C. (Adjutant-General), Vice-Admiral M. M. Denny, C.B., C.B.E., D.S.O. (Third Sea Lord and Controller of the Navy), Lt.-General K. G. McLean, C.B. (Military Secretary to the Secretary of State for War), the Rt. Hon. Lord Bilsland, M.C., LL.D., Sir David Brunt (Secretary of the Royal Society), and a number of distinguished representatives of kindred institutions overseas and at home.

The loyal toasts having been honoured, Field Marshal Sir **William Slim,** G.B.E., K.C.B., D.S.O., M.C., Chief of the Imperial General Staff, proposed the toast of:

"*The Iron and Steel Institute*
and
the Iron and Steel Industry"

coupled with the name of the President of the Institute.

The **President** (Mr. J. R. Menzies-Wilson, O.B.E.), who responded, thanked Sir William Slim on behalf of the Institute and the Industry.

"*The Guests.*"

Mr. **E. W. Senior** (Honorary Member of Council) proposed the toast of "*The Guests,*" coupled with the name of Lord Bilsland.

The Rt. Hon. **Lord Bilsland**, M.C., LL.D., who responded, thanked the President and the Council of the Institute for the invitation to the Dinner and for their kind and friendly hospitality, and thanked Mr. Senior for proposing the toast, and the members of the Institute for the manner in which they honoured it.

SIDNEY GILCHRIST THOMAS COMMEMORATIVE LECTURE

On the occasion of the Annual General Meeting of the Institute, a Lecture in commemoration of Sidney Gilchrist Thomas was given by Mr. James Mitchell, C.B.E., Honorary Treasurer of the Institute, on Wednesday, 26th April, at 8.30 P.M. The President, Mr. J. R. Menzies-Wilson, occupied the Chair.

The **President**, in opening the proceedings, said: We are here tonight to commemorate the centenary of the birth of Sidney Gilchrist Thomas, and in a few moments we are going to hear a Commemorative Lecture by Mr. Mitchell, the Honorary Treasurer of the Institute. We are honoured by the presence of a number of our foreign friends who are attending this Commemoration, and I should like to welcome them by name individually.

I will begin with His Excellency Dr. Clasen, the Luxemburg Minister in the United Kingdom, who is an Honorary Member of The Iron and Steel Institute. Also representing Luxemburg we have with us Mr. Paul List.

I propose to take the rest of the countries in alphabetical order. From Belgium we have Professor Lefebvre, representing the Royal Belgian Society of Engineers and Industrialists, and we also have Professor Coheur, representing the Association of Engineers from the University of Liège.

From France we have Dr. Dupuy, representing the French Society of Metallurgists, and Monsieur Baril, representing the French Society of Civil Engineers. Representing the British Section of the French Society of Civil Engineers, we have with us Mr. Hawthorne and Mr. Howard, and, representing the Institute of Research into Steel, Monsieur Borione.

From Norway we have present with us Mr. Christiansen, representing the Norwegian Metallurgical Society.

From Spain there are present Senor don Isidro Sans Darnis and Senor don Bernabe Chavarri, who represent the Spanish Iron and Steel Institute.

From Sweden we have with us Mr. T. Lundell, who represents the Society of Swedish Engineers in Great Britain.

From Switzerland we have our old friend Professor Durrer of the Swiss Machine Manufacturers Association, who, as you all know, is an Honorary Vice-President of The Iron and Steel Institute.

From a more personal point of view, I think we should all like to extend a most hearty welcome to the relatives and descendants of Sidney Gilchrist Thomas and Percy Gilchrist. We have with us the following sons and daughters of the late Mrs. Thompson, who was the sister of Sidney Gilchrist Thomas: Mr. S. G. Thompson, Mr. Piers Thompson and his two sons, Roger and Perrin, Miss Vera Thompson, and Miss Malys Thompson. We also have with us Mrs. Stacey, the daughter of Sidney Gilchrist Thomas's youngest brother. There is also present the Rev. James Gilchrist, who is the grandson of Percy Gilchrist, and I believe that Mrs. Gilchrist is here too.

We also have representatives from two other bodies; Mr. C. H. Gilkes represents Dulwich College and Mr. R. Lowe represents the World Engineering Conference.

Mr. Mitchell, who is going to give this Commemorative Lecture, is well known to many of you, not only those who belong to this country but also those who come from the Continent. I have no intention of stealing

any of his thunder. You know him as having been connected with the Bessemer process, and he is still connected with it. Having said that, I will ask him to deliver his Lecture.

Mr. **James Mitchell**, C.B.E., then delivered his Lecture, the text of which will be found on pp. 1–8 of the May, 1950, issue of the *Journal*.

The **President**: I now have pleasure in proposing a very hearty vote of thanks to Mr. Mitchell.

The motion was carried by acclamation.

The **President**: As I said earlier in the proceedings, there are present with us several representatives of societies on the Continent, and I know that some of them would like to make a few remarks. I will call first on Monsieur Baril.

Monsieur **Baril**, speaking in French, said: The Society of Civil Engineers of France is happy to be able to take part with you in paying tribute to the memory of that kindly engineer and admirable man, known throughout the world, your fellow-citizen Gilchrist Thomas. His work and the very considerable results which it has had on the development of the industry will be recalled in Paris in a few days' time at a demonstration of gratitude and acknowledgment of indebtedness to which, with the General Chamber of French Steelmaking, the French Society of Metallurgy, and the Franco-English College of the University City of Paris, we have invited your representatives and the highest administrative, scientific, and industrial authorities.

Allow me to add that we are anxious to take this opportunity to assure you of our sincere sympathy and great admiration for you and your country as a whole. Faithful to the generous ideas which were certainly those of your great compatriot, we hope that the *entente cordiale* begun under the reign of Queen Victoria and King Louis Philippe, and renewed and strengthened at the beginning of the present century, will continue to develop. It is not sufficient to take account of the fact that our two peoples have given one another, during two great upheavals, the most wholehearted and loyal support, nor is it sufficient to take account of the fact that on each side of the Channel there live millions of men holding fast to those ideas of liberty without which the development of human personality is impossible; it is also essential that we should take every opportunity of meeting one another so as to understand one another better, to get to know one another better and thus to have a higher regard for one another, and so as to be able to make mutually those concessions which equity demands and which are characteristic of true friends.

Our visit here today, and that which your distinguished representatives have promised to make to us next week, will allow us, I am sure, to make a sincere and reciprocal contribution to this high aim. In thinking that we owe it to the memory of Sidney Gilchrist Thomas, we will revere him with even more respect and gratitude.

Dr. **A. Clasen**: I will be very brief. It is not the rôle of the representative of a small country to speak; I am more often seen but not heard. I feel, however, that as I represent also the Luxemburg Association of Engineers and Industrialists it would be appropriate for me, on the occasion of this commemoration of the centenary of the birth of Sidney Gilchrist Thomas, to pay a tribute to that British inventor, on whose invention the economic prosperity of Luxemburg is based.

It was, I think, a fortnight after the first demonstration at Bolckow Vaughan's that the representatives of the Luxemburg Abetz Company acquired a licence for the Thomas process in Luxemburg, and it was in 1882 that the building of the first Luxemburg Thomas steelworks was started. For Luxemburg the Thomas process was a godsend. In the pre-Thomas era, Luxemburg was a poor agricultural country. The production of pig iron was about 40,000 tons. The country was poor, and Luxemburgers were emigrating in large numbers to the United States. It was the Thomas process which enabled Luxemburg to develop its iron and steel industry to the present level of about 2,500,000 tons, and which at the same time gave it a slag which is an ideal fertilizer and brought prosperity to our agriculture. A production of 2,500,000 tons may not seem much to you, but as we have only 300,000 people in Luxemburg it means 8 tons per head of population, which, I think, compares with about 5 cwt. per head of population in the United Kingdom.

In view of the benefits which this great Englishman brought to our little country, I am inclined to link him with another Englishman, a saint. It was St. Willibord who, about one thousand years ago, brought a revival of Christianity to Luxemburg, and it is less than one hundred years ago that Thomas made his wonderful invention which brought prosperity to our country.

You will appreciate that it was with great gratitude that in Luxemburg, on the 14th and 15th of this month, we celebrated the centenary of the birth of Sidney Gilchrist Thomas. We were happy on that occasion to have as your representative Mr. Paul List, and in the course of those celebrations a memorial plaque was dedicated to Thomas and a special postage stamp was issued. I think you will appreciate also how glad I am to be here on this occasion, how glad I am to congratulate the brilliant Lecturer on an outstanding contribution to the knowledge of an outstanding man, and how glad I am to convey to the President, the Council and the members of The Iron and Steel Institute, the good wishes of the President, the Council, and the members of the Luxemburg Association.

Señor don **Isidro Sans Darnis**: On behalf of the Instituto des Hierro y del Acero, that is, the Spanish Iron and Steel Institute, and therefore also in the name of all who in Spain are connected with iron and steel—because our Institute, although founded only three years ago, has already one thousand members and associates—it gives me great pleasure to be among you at this Annual Meeting, in response to the kind invitation of your Institute, and to be present at the commemorative celebration of the centenary of the birth of Sidney Gilchrist Thomas. This eminent metallurgist contributed greatly to the development of the world's iron and steel with the basic conversion process, thanks to his exceptional abilities and sparkling mind, which we Spanish people profoundly admire. Your country can be really proud of him. Again I thank your Institute for the cordial invitation with which you honoured us.

Professor **R. Durrer**: The Verein Schweizerischer Maschinen-Industrieller, that is, the Association of Swiss Machine Manufacturers, which includes some iron and steel producers, wishes me to express its cordial greetings to the Institute and its best wishes for this meeting and for the future of the Institute.

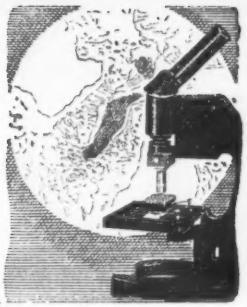
In Switzerland we shall never forget the special Summer Meeting in 1947, when representatives of the great British iron and steel industry visited our small country and our still smaller iron and steel industry.

I should like to add to these greetings and good wishes my personal ones, based on many years' membership of your Institute and my feelings of very sincere friendship towards you.

The **President**: That concludes the proceedings this evening. I think you will all agree that we have had a most interesting meeting, and I hope that some of you have found it as instructive as I have.

B. I. S. R. A.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION



The Adherence of Sand on Steel Castings

By P. R. Beeley, B.Met., and H. T. Protheroe, B.Sc.

SYNOPSIS

The first part of the paper details methods employed for the visual comparison of the degree of roughness on steel castings, and for a numerical assessment of penetration.

A relationship between metal penetration and sand adherence has been established. The temperature limit at which adherence occurs, in the case of the standard casting adopted, has been determined for casting temperature, metal composition, and sand conditions.

The conditions at the sand/metal interface are considered in relation to adherence, and an explanation of the mechanism of adherence is given. The product of the reaction between the metal and sand is the iron silicate $2FeO.SiO_2$.

A second section deals with the effect of varying the bond of the sand. The relative merits of various mould paints have been determined; Corefrax, sillimanite, fused alumina, zircon, and plumbago are compared with silica flour. The effect of changing the bond in any paint has also been investigated.

An examination of some industrial samples exhibiting severe burning-on is included.

THE MECHANISM OF SAND ADHERENCE

THE problem of improving the surface finish of steel castings and of reducing fettling costs has received much attention from time to time. A review of the literature compiled by one of the authors[1] gives a résumé of the methods and findings of previous investigators.

Looseness in nomenclature has resulted in some confusion regarding the true meaning of some of the terms used. 'Metal penetration' is often confused with 'oxide or slag penetration,' and sometimes it is used to mean 'burning-on' or 'sand adherence.'

In this paper distinction will be made between metal penetration and oxide or slag penetration. The term 'burning-on' will be synonymous with 'sand adherence.'

A perusal of the previous work[1] has indicated that metal penetration is always associated with burning-on, whereas when oxide or slag penetration is encountered the castings often strip easily and cleanly. The term 'limit of penetration' is used to mean the 'limit of penetration at which sand adherence occurs.'

EXPERIMENTAL PROCEDURE

An attempt has been made to determine the most potent factors affecting penetration and burning-on and to understand the mechanism of these phenomena. Except in cases where certain factors were deliberately altered to obtain specific information regarding their potency, a standard procedure with regard to moulding, ramming, and melting has been adopted. This was to ensure that contributory factors were operative or inoperative to the same extent in each case.

The pattern used was a 3·5-in. cube which, when cast, gave a cube of these dimensions with a 2 × 1-in. channel (*see* Figs. 1 and 2). This was obtained on the casting by means of a separately rammed core. The core was rammed on an A.F.A. standard rammer, the plunger and core-box of which had been modified to suit the requirements of the standard casting. It was always inserted in such a way that the topmost surface in the core-box, *i.e.*, the surface that came in contact with the plunger, became the casting surface in the mould. Variables due to uneven ramming, etc., were thus eliminated.

The channel ensured a sand surface free from exposure to radiation from the rising molten metal, thus minimizing the local spalling of sand grains from the surface. Further, the surface was in such a position with respect to the ingates that it was free from extensive erosion by the metal during pouring.

A condensed version of paper SC/A/8/50 of the Melting and Metallurgical Committee of the Steel Castings Division of the British Iron and Steel Research Association, received 4th May, 1950.

Mr. Beeley, until recently a holder of a B.I.S.R.A. bursary at Sheffield University, is now at Messrs. Hadfields, Ltd., Sheffield. Mr. Protheroe is a Lecturer in Foundry Metallurgy at Sheffield University.

Various stylus instruments were used to assess the degree of surface roughness obtained, but they proved entirely unsuitable, particularly where considerable metal penetration had occurred. Their use was further complicated by the presence of adhering sand.

The method finally adopted was visual profile examination. The profiles (*see*, for example, Fig. 3) were obtained by sectioning the casting through the centre-line at right-angles to the upper surface of the channel. These sections were surface-ground, mounted in Wood's alloy, and polished as for micro-examination. The Wood's alloy was removed by immersing the specimen in boiling water. Photographic repro-

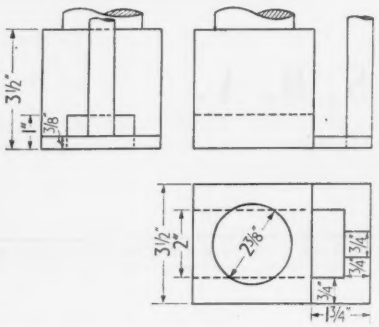


Fig. 1—Dimensions of standard casting

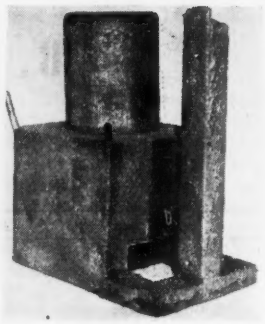


Fig. 2—Standard casting showing ingates

Table I

SIEVE ANALYSIS OF SANDS

Percentage Retained on B.S.I. Sieve No.	Arnold's No. 52, %					Olivine Sand
	100	0	90	75	50	
	Arnold's No. 26A, %					
	0	100	10	25	50	
10	0·3	0·0	0·8	0·3	0·5	0·2
16	7·2	0·7	5·9	4·4	3·6	7·5
22	18·8	0·9	14·4	11·0	9·1	3·8
30	34·6	1·1	31·8	27·2	18·2	7·2
44	30·9	1·8	26·5	23·9	15·4	15·9
60	7·3	5·9	9·4	8·5	6·7	21·4
72	0·6	8·2	1·5	2·0	3·8	11·7
100	0·2	36·5	8·6	8·0	16·7	18·9
150	0·1	39·9	0·9	13·4	23·4	9·2
200	0·0	4·2	0·1	1·1	2·3	2·3
Passed 200	0·0	0·8	0·1	0·2	0·3	1·9
Total	100·0	100·0	100·0	100·0	100·0	100·0

Table II

PHYSICAL PROPERTIES OF SAND MIXTURES

Sand Mixture			Green Comp., lb./sq. in.	Dry Comp., lb./sq. in.	Permeability
Arnold's No. 52, %	Arnold's No. 26A, %	Additions			
100	0	+ 4% Bentonite	5·6	19·0	602
0	100	+ 4% Bentonite	7·0	61·0	75
90	10	+ 4% Bentonite	5·9	31·0	383
75	25	+ 4% Bentonite	6·4	49·0	188
50	50	+ 4% Bentonite	6·7	55·0	94
100	0	+ 4% Fulbond No. 3A	3·7	12·0	600
100	0	+ 4% Bentonite, 1% starch	4·9	2·7	627
100	0	+ 4% Bentonite, 5% Fe_2O_3	9·6	35·0	645
100	0	+ 9·5% cement	0·5	46·0	430
Olivine sand		+ 4% Bentonite	10·8	41·0	123

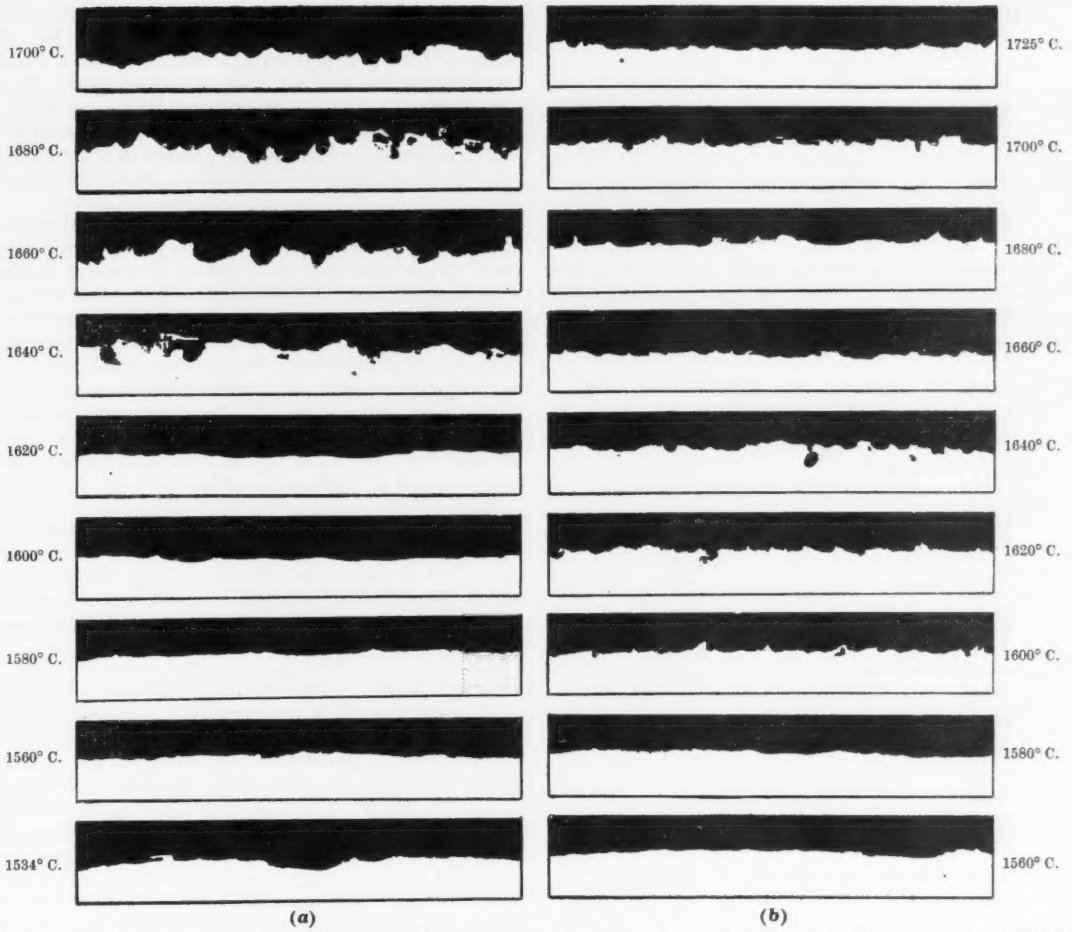


Fig. 3—Variation in profile irregularities with casting temperature: (*a*) Arnold's No. 52 silica sand, (*b*) Arnold's No. 26*A* silica sand × 15 (reduced × ½ linear in reproduction)

duction at a magnification of × 15 gave satisfactory visual comparison.

To obtain a numerical assessment of the depth of the irregularities on each profile, a microscope incorporating two adjustable knife-edges was employed, these being positioned to correspond with points of maximum and minimum penetration visible in each field. The specimen was traversed across the stage of the microscope and 20 readings, at equally spaced intervals along the profile, were taken. The readings were averaged to give a value of metal penetration in millimetres.

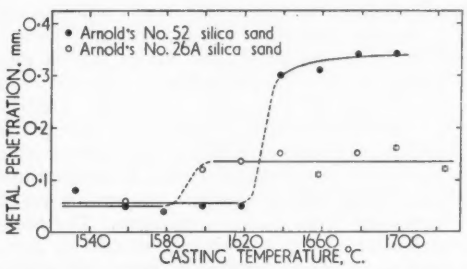


Fig. 4—Relationship between metal penetration and casting temperature

EXPERIMENTAL RESULTS

Effect of Casting Temperature

To explore the effect of casting temperature two series of experiments were conducted, one with a coarse sand, Arnold's No. 52, and one with a fine sand, Arnold's No. 26*A*. Details of these sands are given in Tables I and II, and their chemical analyses are given on page 144.

The metal was melted in a high-frequency furnace under conditions as near standard as possible, the final composition falling within the following limits :

C, %	Mn, %	Si, %	S, %	P, %
0·21–0·24	0·6–0·8	0·25–0·31	0·032	0·032

The moulds were cast at intervals of 20° over the range 1540–1700° C.

Chemical Analyses of Base Sands

	Arnold's No. 52 %	Arnold's No. 26A %
SiO_2	97·9	95·4
Fe_2O_3	0·53	1·55
FeO	...	...
Al_2O_3	0·99	1·45
TiO_2	Trace	0·32
CaO	0·48	0·40
MgO	Trace	0·05
Na_2O	0·06	0·09
K_2O	...	...
MnO	Trace	Trace

The numerical assessment of the extent of surface irregularities is given below, the profile photographs being shown in Fig. 3 ; the same results are also shown graphically in Fig. 4 :

Variation in Penetration and State of Surface with Casting Temperature

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
Arnold's No. 52 Sand		
1700	0·34	Adhering sand
1680	0·34	,, ,,
1660	0·31	,, ,,
1640	0·30	,, ,,
1620	0·05	Smooth
1600	0·05	,,
1580	0·04	,,
1560	0·05	,,
1534	0·08	Smooth, slight cold lapping
Arnold's No. 26A Sand		
1725	0·12	Adhering sand
1700	0·16	,, ,,
1680	0·15	,, ,,
1660	0·11	,, ,,
1640	0·15	,, ,,
1620	0·13	,, ,,
1600	0·12	,, ,,
1580	0·04	Smooth
1560	0·06	,,

In the case of the coarse sand, it will be observed that there is a noticeable change in the surface irregularities between a casting temperature of 1620° and 1640° C., whilst with the finer sand the change occurs between 1580° and 1600° C. In both cases, this increase in the degree of metal penetration is accompanied by sand adherence. Although the temperature limit of penetration (*i.e.*, the temperature at which surface irregularities become pronounced) is higher with the coarse sand than with the fine one, it is also obvious that the depth of penetration is less in the latter instance. It is therefore indicated that for a given sand mixture a critical set of conditions exists at a certain temperature, where the rate of heat transfer from the steel to the sand becomes sufficiently great, compared with the rate of dissipation of heat through the sand, to permit metal to flow between the sand grains. Below the temperature limit of penetration the difference between heat transfer and heat dissipation is such that a restrictive solid skin is formed at the metal/mould interface or just inside the pore spaces of the sand itself, and extensive penetration does not occur. As the temperature increases above the limit, the metal penetrates to a greater depth.

Lucks[2] and his co-workers showed that a fine-sand aggregate has a lower thermal conductivity than a coarse-sand aggregate of similar composition. The rate of heat dissipation of the fine No. 26*A* sand is therefore slower than that of the coarse No. 52 sand, so that penetration will commence at a lower temperature for a given mass of molten steel. It is also apparent that the critical conditions are dependent to a large extent upon casting temperature, which is therefore an important factor in determining whether sand adherence will occur. As will be shown later, however, it is not an independent factor.

This dependence on the existence of critical conditions, in conjunction with the observed sudden occurrence of penetration, is put forward to account for the fact that castings are often obtained with certain portions of the surface completely smooth and free from adhering sand, whilst adjacent areas exhibit penetration and sand adherence. A relatively small difference in temperature will determine whether burning-on takes place or is absent altogether, and in such castings this difference can exist locally as a result of heat flow, convection, and similar factors. This phenomenon is illustrated in Fig. 5.

The sudden occurrence of penetration within a 20° C. limit of temperature was fairly consistent throughout the research and has been used to assess the effect of other variables by noting whether this temperature limit of penetration was raised or lowered. Large variations in actual depth of penetration were not encountered.

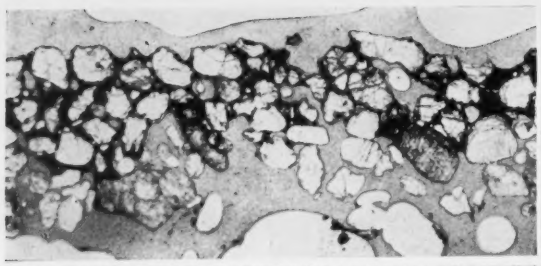
Reactions at the Sand/Metal Interface

It is obvious that reactions at the sand/metal interface must be considered before any definite conclusions can be drawn regarding the mechanism of burning-on. That such reactions occur is beyond dispute, the work of Dietert, Doelman, and Bennet[3] proving conclusively that reactions occur even at temperatures below the solidus. An examination of the moulding material adjacent to the surface from any casting will reveal that certain conspicuous changes have taken place. When a casting strips cleanly or when penetration is not excessive the sand from the interface peels away in the form of a coherent cake. In mild cases of penetration, only a little sand is left adhering to the casting. In severe cases the sand must be removed by mechanical means. A sample of sand cake is shown in Fig. 6.

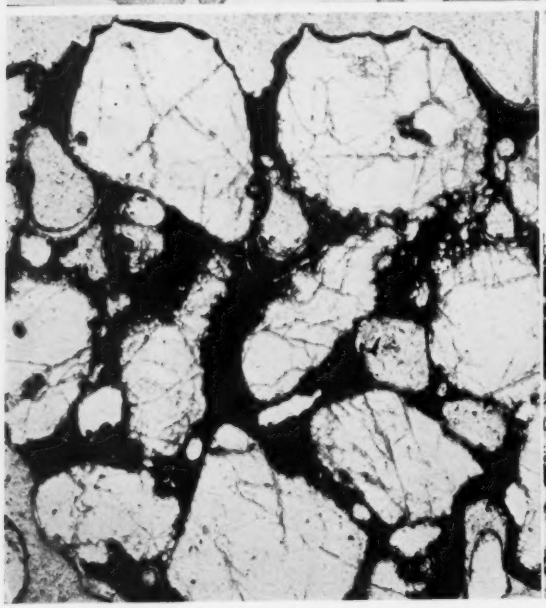
Three methods of examination can be employed : petrological, X-ray, and chemical analysis. Samples were obtained from the interface of castings poured at 1534°, 1600°, and 1660° C., the moulding sand being Arnold's No. 52. The sand aggregate, after removal from the casting, was impregnated with a Bakelite resin, and a thin translucent section at right-angles to the interface was prepared. This was examined by transmitted light, and a typical photomicrograph is reproduced in Fig. 7. It shows that the original quartz grains are practically unaltered, but as a result of casting they have become partially surrounded by a dark slag constituent penetrating in some instances to a depth of 3 mm. It is undoubtedly this constituent which cements the grains together and forms the bond in the sand cake. The amount or distribution of this constituent seemed to have no significance, a fact confirmed later by chemical analysis.

Fig. 6—Sand cake taken from casting surface

Fig. 5—Casting surface showing light zone, free from adhering sand, and dark zone, with adhering sand

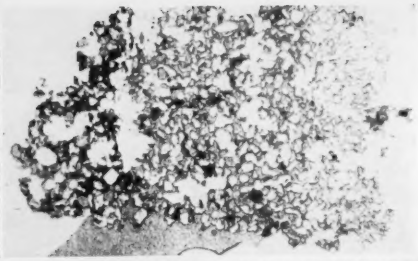


(a)
× 10

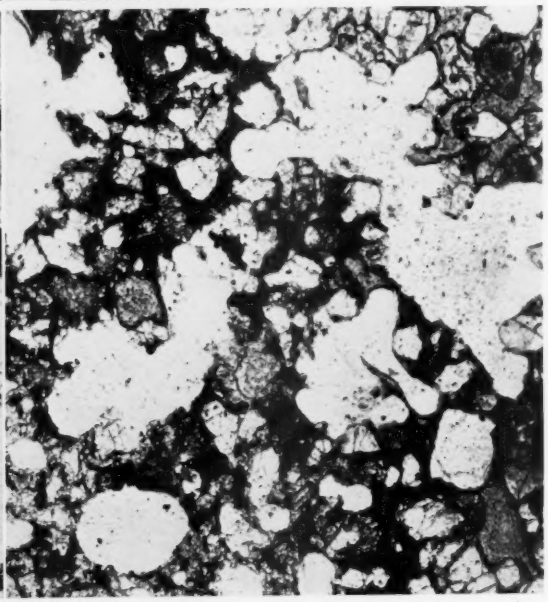


(b)
× 40

Fig. 7—Penetration of slag into Arnold's No. 52 sand at 1534° C.

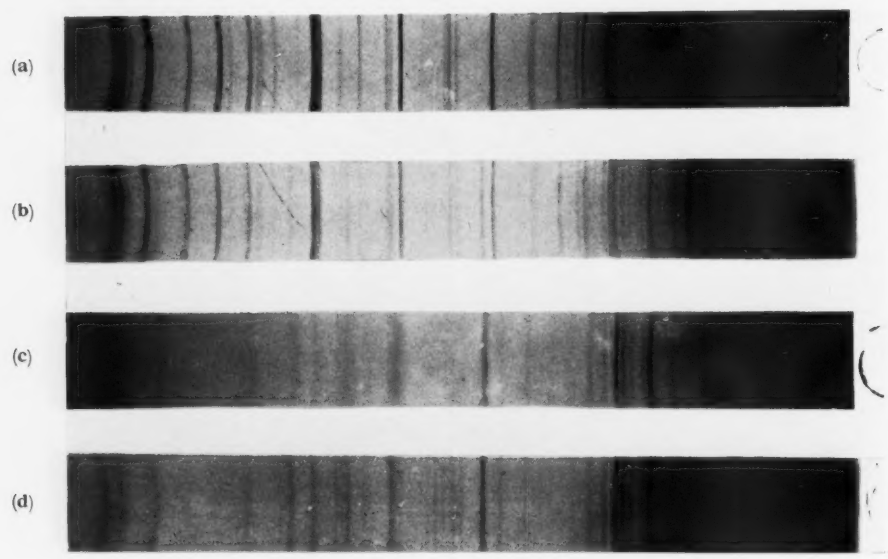


(a)
× 10



(b)
40

Fig. 8—Penetration of slag into Arnold's No. 26*A* sand at 1660° C.



(a) Moulding sand
(b) Sand aggregate after casting
(c) Sample of fayalite
(d) Separated compounds from aggregate

Fig. 9—X-ray diffraction patterns

A similar photograph of a section obtained from a mould of the finer Arnold's No. 26*A* cast at 1600° C. is shown in Fig. 8. Some difficulty was experienced in obtaining this section because impregnation of the sand was not so extensive as in the former case, and some grains were lost during preparation. Slag penetration had, however, occurred as is shown in Fig. 8.

A chemical analysis of the sand aggregate gave the following composition :

	%		%
SiO_2	87·96	TiO_2	Trace
Fe_2O_3	1·57	CaO	0·43
FeO	9·22	MgO	Trace
MnO	0·01	Na_2O	0·06
Al_2O_3	0·89	K_2O	...

When compared with the analysis of the original sand, it shows that the major change in composition is an increase in iron compounds, ferrous iron predominating. The difficulty in obtaining true comparisons between the amounts of compounds absorbed under different conditions lies in the fact that variable amounts of free silica may be included in different samples. Silica values thus become meaningless. To overcome this difficulty, the following procedure was adopted to examine absorption in all the experiments conducted in the previous series.

The sand aggregate was stripped from the surface of the casting to a depth sufficient to include all material that had obviously been affected by the molten steel. The outline of the cake was then traced on to paper and the area of the tracing was determined by means of a planimeter. The cake was weighed, thoroughly pulverized, and a sample was taken for analysis. By this method, although the iron and manganese oxide figures had no meaning as actual percentages, comparable figures were obtained for the approximate absorption over unit area of casting surface. The calculation was as follows :

$$\text{FeO} = \frac{Wn}{100A} \text{ mg./sq. cm.}$$

where A = measured area of aggregate (sq. cm.)
W = total weight of aggregate (mg.)
n = FeO content of sample.

A similar method is used for MnO and Fe_2O_3.

In conducting the analysis, the total iron was first estimated and then a separate determination of ferrous iron was made by the hydrofluoric acid extraction method. The ferric iron was determined by difference. The results obtained from the two series of castings are given in Table III. It is evident from these results that there is no appreciable increase in the amounts of absorbed compounds with increase in casting temperature. It is significant that there is no sudden increase in the amounts absorbed corresponding to the sudden increase in metal penetration previously referred to. It appears, therefore, that metal penetration cannot be correlated with slag reaction at the mould face.

The average absorption figures in milligrammes per square centimetre are as follows :

	Ferrous Iron	Ferric Iron	Manganese
Arnold's No. 52	34·7	3·6	1·0
Arnold's No. 26*A*	50·8	6·5	2·2

After allowing for the ferric oxide present in the original sands (*see* p. 144), only relatively small amounts of ferric iron are present in the absorbed compounds. These materials therefore consist principally of a ferrous compound, the whole of which is formed as a result of a reaction at the interface. The most probable product of the reaction is the orthosilicate (fayalite, $2FeO.SiO_2$), the presence of which was confirmed by X-ray examination.

In Fig. 9, (*a*) is the X-ray diffraction pattern of a sample of the moulding sand, (*b*) of a sand aggregate from a casting, and (*c*) of a sample of fayalite. Several lines are present in (*b*) which are not present in (*a*) and can only be due to a phase resulting from a

Table III

ANALYSES OF SAND AGGREGATES

(Giving oxide content per unit area of casting surface)

Casting Temp., °C.	Sand Area, sq. cm.	Weight of Sand, gm.	Analysis, %			Ferrous Iron, mg./sq. cm.	Ferric Iron, mg./sq. cm.	Mn, mg./sq. cm.
			FeO	Fe_2O_3	MnO			
Coarse-Grained Sand								
1534	58·5	23·53	9·85	1·03	0·35	30·8	2·78	1·09
1560	62·6	29·84	7·98	1·11	0·32	29·5	3·70	1·18
1580	50·7	26·78	7·72	1·00	0·28	31·7	3·69	1·15
1600	53·2	26·04	9·23	1·32	0·21	35·1	4·52	0·80
1620	54·5	26·26	9·63	0·87	0·21	36·1	2·93	0·78
1640	48·4	28·37	8·74	0·64	0·25	39·8	2·62	1·14
1660	32·5	19·80	8·34	1·09	0·18	39·5	4·64	0·85
Fine-Grained Sand								
1560	55·8	26·74	14·76	1·17	0·37	55·0	3·92	1·37
1580	58·0	29·23	13·04	2·34	0·20	51·2	8·25	1·55
1600	54·8	30·11	12·33	1·04	0·45	52·6	4·77	1·91
1620	65·9	46·31	8·82	1·10	0·48	48·2	5·40	2·61
1640	69·9	46·76	8·55	1·60	0·45	44·5	7·49	2·33
1660	64·5	40·03	10·35	2·01	0·34	49·9	8·72	1·63
1680	69·0	40·01	12·15	1·72	0·25	54·7	6·97	1·12
1700	67·3	43·28	9·99	1·52	0·64	49·9	6·84	3·19
1725	74·8	55·99	9·73	1·11	0·72	50·8	5·81	4·17

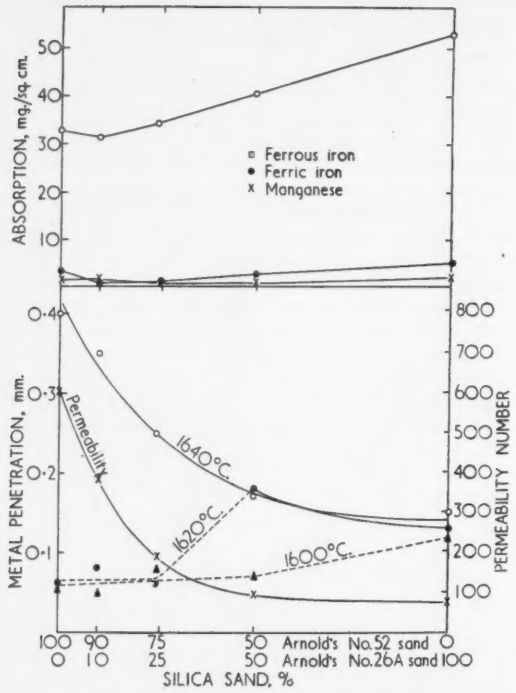


Fig. 10 (*top*)—Variation in absorption with varying proportions of coarse and fine sand

Fig. 11—Effect of various proportions of coarse and fine sand on penetration and permeability

reaction at the sand/metal interface. The additional lines in this pattern are also present in the fayalite pattern and the ring diameters are identical.

To confirm the presence of fayalite in the aggregate and to obtain a more intense pattern, a further sample was mechanically separated into quartz and the new compound by making use of their difference in specific gravity. The crushed sample was shaken thoroughly with bromoform and was allowed to settle in a dropping funnel. The specific gravity of bromoform is 2·84, being between that of quartz and the heavier compound. The quartz remained suspended while the compound sank into the neck of the funnel from which it was collected. The X-ray pattern obtained is shown in Fig. 9*d*.

It seems definite, therefore, that the sand from the face of the mould after casting consists primarily of unchanged quartz and ferrous silicate. The small amount of ferric iron is probably present as the oxide, Sosman and Hostetter[4] having established that a ferric silicate does not normally exist.

Effect of Sand Conditions

Grain Size—Caine,[5] in investigating the effect of the grain size of sand, found that metal penetration decreased with decreasing grain size. He concluded that there was a direct relationship between adherence and the surface sintering temperature of the sand. He reasoned that the lowering of the sintering point with diminishing grain size led to progressive fusion and resultant closing of the surface pores of the sand, and consequently the entry of the metal between the grains was impeded.

Skin sintering temperature, however, is only one of a number of properties dependent upon grain size, and this relationship may well be only a manifestation of some other relationship.

Ljunggren[6] found similar results and reported an increase in adherence corresponding with increases in permeability, grain size, and sintering point. A subsequent determination of partial correlation coefficients conducted on Llunggren's results[7] indicated that the true major relationship was that between adherence and permeability.

The following investigation was carried out on sand mixtures consisting basically of the same sands as were used previously. Varying proportions of each were milled together so as to alter the permeability of the mixtures. Sand testing results and mechanical gradings are given in Tables I and II.

Table IV gives the casting results at temperatures between 1600° and 1640° C. The absorption graph is

Table IV

INFLUENCE OF PERMEABILITY ON PENETRATION AND ADHERENCE

Arnold's No. 52, %	Arnold's No. 26A, %	Permeability No.	Casting Temp., °C.	Average Depth of Profile Irregs., mm.	State of Surface
100	0	602	1640	0·40	Adhering sand
			1620	0·06	Smooth
			1600	0·06	,,
90	10	383	1640	0·35	Adhering sand
			1620	0·08	Smooth
			1600	0·05	,,
75	25	188	1640	0·25	Adhering sand
			1620	0·06	Smooth
			1600	0·08	,,
50	50	94	1640	0·17	Adhering sand
			1620	0·18	,, ,,
			1600	0·07	Smooth
0	100	75	1640	0·15	Adhering sand
			1620	0·13	,, ,,
			1600	0·12	,, ,,

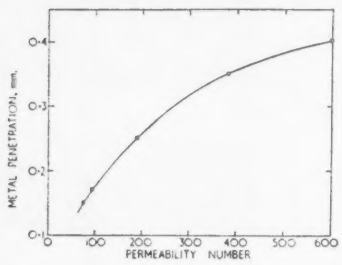


Fig. 12—Direct relationship between metal penetration and permeability; casting temperature 1640° C.

shown in Fig. 10 and indicates a progressive increase in the amount of absorption as the sand mixture becomes finer.

Figure 11 represents graphically the depth of penetration with varying degrees of fineness, together with the permeability curve. With a casting temperature of 1640° C. penetration is sufficiently severe to cause adherence, regardless of grain size. The depth of penetration, however, diminishes with diminishing grain size and follows a similar trend to the permeability curve. With a casting temperature of 1620° C. penetration is not severe enough to cause adherence in the more permeable mixtures, but is so in the less permeable sands and again the depth of penetration diminishes with diminishing grain size. At 1600° C. penetration is not severe enough to cause adherence, except in the case of the least permeable sand.

The relationship between adherence and permeability established upon the results of Caine[5] and of Ljunggren[6] is therefore valid only at casting temperatures high enough for adherence to occur, irrespective of the grain size of the sand. Such a relationship, based on the results obtained at 1640° C., is reproduced in Fig. 12.

Ramming Density—In all previous experiments a standard degree of ramming was employed, using ten blows of the rammer. In the series on the effect of permeability, variations in this property were obtained by varying the relative proportions of coarse and fine sand. One consequence of using a standard ramming technique is a variation in bulk density from the sand layers adjacent to the rammer to those farther away. This has been illustrated by Davies and Rees.[8]

Table V

EFFECT OF VARYING RAMMING DENSITY ON MOULD HARDNESS AND PENETRATION

No. of Rammer Blows	Sand No. 52		Sand No. 26A	
	Average Mould Hardness	Av. Depth of Profile Irregs., mm.	Average Mould Hardness	Av. Depth of Profile Irregs., mm.
1	44·0	0·46	58·5	0·24
2	66·9	0·44	66·8	0·26
3	70·0	0·39	72·0	0·25
7	78·0	0·45	85·0	0·16
10	78·3	0·40	87·5	0·15
15	81·0	0·37	88·0	0·12

The results given in Table V were obtained from two series of castings, one using the coarse sand and one the fine sand. The object was to determine the effect, if any, of the extreme conditions of excessively hard-rammed sand, and of loosely rammed sand, on penetration.

Variations in surface hardness were obtained by varying the number of blows of the rammer and adjusting the weight of sand to maintain the correct size of sand block. All the moulds were cast at 1680° C., a temperature at which it was known that penetration would occur.

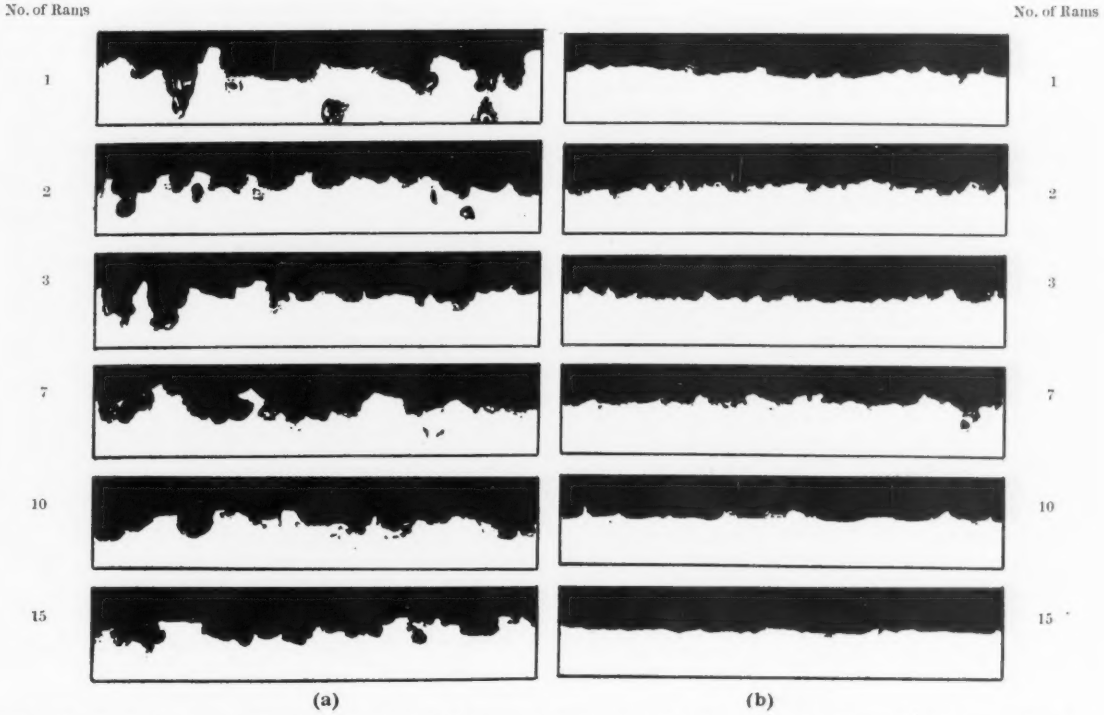


Fig. 13—Variation in profile irregularities with ramming density : (*a*) Arnold's No. 52 sand, (*b*) Arnold's No. 26*A* sand × 15 (reduced × ½ linear in reproduction)

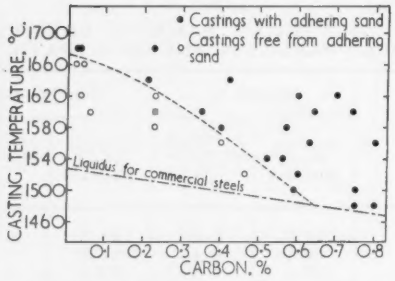


Fig. 14—Casting temperature limit of penetration in relation to the liquidus

Table V shows that the degree of ramming influences mould hardness to a considerable extent until a certain value is obtained, after which further ramming has little effect. With regard to penetration, Fig. 13, there is little variation in the case of the coarse sand. The fine sand does show a tendency to a proportionate decrease in penetration as the amount of ramming increases. It was felt, however, that the objective of deliberately reproducing conditions analagous to soft spots encountered in badly rammed moulds had not been achieved. The lowest hardness values employed were the absolute minima that could be tolerated to enable the sand blocks to be handled.

Effect of Metal Composition and Interface Temperatures

From the results so far obtained it is more or less evident that penetration is affected principally by temperature, and secondly by the nature of the moulding material, particularly with regard to its relative compactness or permeability. However, a relationship between penetration and permeability exists only in those cases where the casting temperature is high. This seems to suggest that the operative conditions are linked up, firstly, with some inherent property of the metal itself that is readily affected by temperature and, secondly, by the conditions existing at the sand/metal interface.

For a given steel the incidence of penetration does not become severe enough to cause sand adherence until a certain casting temperature is reached, and this temperature is different according to whether the moulding material is relatively coarse or fine. As, in each case, the depth of penetration increases as the temperature increases, it appears that the conditions at the interface are also dependent on the casting temperature. Reactions at the interface are more or less independent of the temperature in the range investigated and, as previously mentioned,[3] can occur after solidification. It has also been shown that the reaction does not affect penetration as such, although it might affect the ease of stripping of the mould.

It is reasonable to conclude that the property of the metal most readily affected by temperature is fluidity—the property most likely to govern the ease with which the metal will flow into the pore spaces of the sand. For a given casting temperature, however, the fluidity will depend upon the composition. The conditions existing, therefore, at the interface, although depending on casting temperature, will become effective or non-effective, with respect to penetration, according to the composition of the steel.

A series of experiments was conducted on steels of carbon content from 0·04 to 0·8%. For each steel a sufficient number of casts was made to fix the temperature limit of penetration at which adherence occurred. The results are plotted in Fig. 14, and the position of the penetration limit, with respect to the liquidus, is shown for each composition. It is rather revealing in that it demonstrates that penetration and adherence occur at lower temperatures as the carbon content increases. This, perhaps, might have been expected, but it is noticeable that as the carbon content increases so the degree of permissible superheat above the liquidus is reduced if penetration is to be avoided. With carbon contents approaching 0·6% or over, penetration occurs at temperatures only just above the liquidus. This led to a consideration of cast-iron castings, which are generally accepted as possessing superior surface finishes to steel castings. This apparent incongruity is due to the fact that refractoriness of sands for these castings is of minor importance and fine-grained sands are normally employed, which in itself inhibits penetration if the casting temperature is not too high.

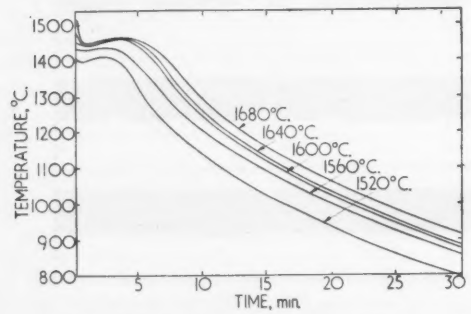


Fig. 15—Interface cooling curves for various casting temperatures

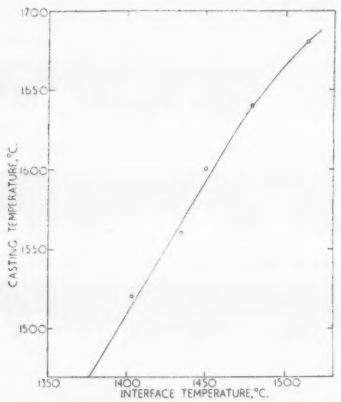


Fig. 16—Relationship between casting temperatures and interface temperatures

This is verified by the results shown below, obtained by casting into moulds of the coarse silica sand :

Results Obtained with Cast Iron for Various Casting Temperatures

Composition : 3·32% C, 1·29% Si, 0·5% Mn, 0·014% S, 0·014% P

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
1350	0·35	Adhering sand
1270	0·28	,, ,,
1240	0·30	,, ,,

It is seen that penetration and adherence occur, in spite of the very low casting temperature compared with that of steel.

The differences in allowable superheat for different carbon contents must depend on the conditions existing at the interface and the extent to which these conditions are controlled by casting temperature. The curves in Fig. 15 show the interface temperatures existing at various times after casting and were

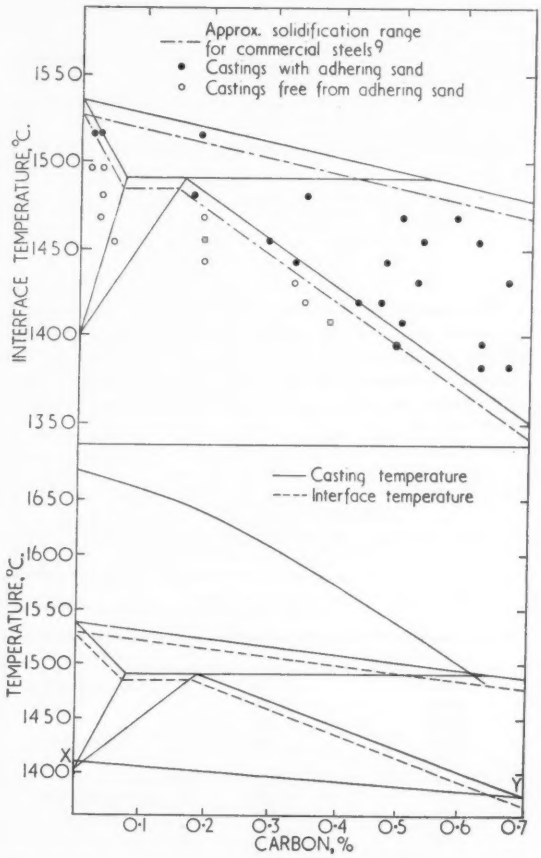


Fig. 17 (*top*)—Interface temperature limit of penetration in relation to the solidification range

Fig. 18—Approximate positions of casting temperature and interface temperature limits of penetration in relation to solidification range

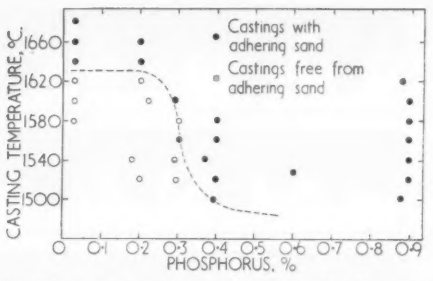


Fig. 19—Effect of phosphorus on the limit of penetration

determined for the casting temperatures indicated. They apply only to the standard casting used in this research. Bare thermocouples were inserted in the moulds at the upper surface of the sand blocks. A graphical relationship was established between casting temperature and the temperature recorded instantaneously upon contact between metal and sand. This is shown in Fig. 16 and was used to determine the interface temperatures for the castings under consideration.

In Fig. 17 the iron–carbon diagram is reproduced, together with the approximate solidification range for commercial steels.[9] The position with regard to interface temperatures for each carbon steel is shown so that interface temperatures can be considered in

Table VI

RESULTS OBTAINED FROM STEELS OF VARYING PHOSPHORUS CONTENT

Content of other elements in each case: 0·23% C, 0·6% Mn, 0·31% Si, 0·032% S

Casting Temperature, °C.	Average Depth of Profile Irregularities, mm.	State of Surface
0·2% Phosphorus		
1660	0·57	Adhering sand
1640	0·46	,, ,,
1620	0·10	Smooth
1600	0·08	,,
1540	0·12	,,
1520	0·07	,,
0·3% Phosphorus		
1600	0·40	Adhering sand
1580	0·07	Smooth
1560	0·18	Local adherence
1540	0·13	Smooth
1520	0·12	,,
0·4% Phosphorus		
1580	0·40	Adhering sand
1560	0·49	,, ,,
1540	0·52	,, ,,
1520	0·58	,, ,,
1500	0·19	Local adherence
0·9% Phosphorus		
1620	1·34	Adhering sand
1600	1·32	,, ,,
1580	1·36	,, ,,
1560	1·21	,, ,,
1540	1·32	,, ,,
1520	1·45	,, ,,
1500	1·42	,, ,,

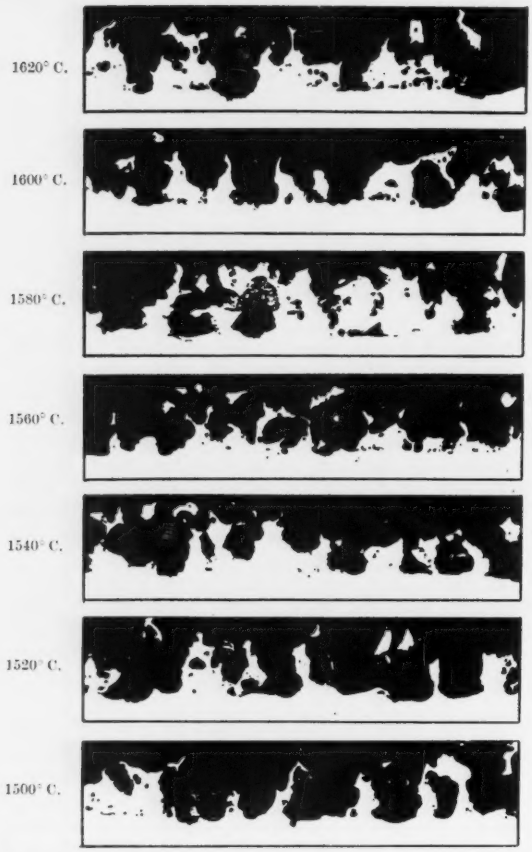


Fig. 20—Profile irregularities obtained from a 0·9% phosphorus steel
× 15 (reduced × ½ linear in reproduction)

relation to the solidification range and according to whether or not the castings exhibit penetration and sand adherence.

It can be seen from the diagram that the interface temperature limit of penetration closely follows the solidus for steels within the composition range investigated. If the steel is cast at a sufficiently low temperature to give an interface temperature below the solidus, penetration does not occur. If, on the other hand, the casting temperature is high enough to cause an interface temperature above the solidus, penetration will result.

The approximate casting temperature limits and interface temperature limits of penetration are shown together in Fig. 18. It was impossible to cast steels of high carbon content without obtaining penetration, even if the steel was poured when excessively sluggish, *i.e.*, in the neighbourhood of the liquidus. This is because the solidification range of steels with above 0·65% of carbon is so wide, compared with the drop in temperature from casting, that the interface temperatures are not brought below the solidus. If the lowest possible casting temperature for each steel is arbitrarily taken to be just above the liquidus, interface temperatures would lie on the line XY in Fig. 18. This cuts the solidus at a position corresponding to just over 0·6% of carbon. As the casting temperature is raised, the position of XY is also raised and cuts the solidus at a position corresponding to a lower carbon content.

The casting temperature, although the most potent factor controlling penetration, is not an independent factor. It controls the conditions at the interface, but the extent to which these conditions affect penetration depends on the composition of the steel. For a given set of conditions, as represented by the line XY or by any other position of XY, the extent of penetration will be determined by the ' fluid life ' which, in turn, depends on composition.

Table VI and Fig. 19, giving the results of penetration tests on steels of varying phosphorus contents, verify this fact. At 0·2% of phosphorus the position of the temperature limit of penetration is unaltered, although the depths of penetration above this limit are slightly greater than with steels of lower phosphorus content. At 0·9% of phosphorus the castings show very deep penetration at all casting temperatures, as illustrated in Fig. 20. Research[10] has indicated that phosphorus up to 0·2% exerts no influence on the fluidity of steels of constant carbon content. Steels of 0·6% of phosphorus or over, however, possess greatly increased fluidity.

The results obtained from a series of chromium steels are given in Table VII.

The approximate limits of penetration are therefore as follows :

Chromium, %	Temperature Limit of Penetration, °C.
0	1620–1640
1	1600–1620
5	1620–1640
15	1580–1600

The absorption of chromium oxide by the surface layers of the sand is indicated in Fig. 21. Slightly greater quantities of chromium are absorbed as the chromium content of the steel increases, and at the same time there is a decrease in the absorption of other oxides.

Table VII

RESULTS OBTAINED FROM STEELS OF VARYING CHROMIUM CONTENT

Content of other elements in each case: 0·6% Mn, 0·032% P, 0·032% S

Casting Temp., °C.	Av. Depth of Profile Irregs., mm.	State of Surface
1·05% Cr (0·23% C, 0·31% Si)		
1660	0·37	Adhering sand
1640	0·29	,, ,,
1620	0·34	,, ,,
1600	0·06	Smooth
5·01% Cr (0·24% C, 0·31% Si)		
1640	0·26	Adhering sand
1620	0·09	Smooth
1600	0·09	,,
14·22% Cr (0·31% C, 0·27% Si)		
1640	0·36	Adhering sand
1620	0·20	,, ,,
1600	0·19	,, ,,
1580	0·08	Smooth

Little accurate data have been published concerning the solidification range of the iron–chromium–carbon system, but recent work[10] has shown these steels to possess greater fluidity at low temperatures than plain carbon steels. Further, there is practically no difference in fluidity in chromium steels themselves between 1% and 11% of chromium. The lowering of the temperature limit of penetration with 1% of chromium may therefore be due to increased fluidity. However, at 5% of chromium the fluidity is practically the same, yet the temperature limit of penetration rises back to the level of the plain carbon steel. This may be due to the restrictive surface oxide film of the type known to exist on chromium steels. The retarding effect of such a film would be of greater significance in the constricted voids between the sand grains than in the spiral of the fluidity test.

The lowering of the limit at 15% of chromium is probably due to the widening of the solidification range with this amount of chromium. The surface-film effect might be expected to exert a greater influence in retarding fluidity in view of the greater amount of chromium. An examination of Fig. 21, however, shows that the increase in chromium oxide absorption by the sand between 5 and 15% of chromium is very small. It seems justifiable to assume that the rates of film formation on the liquid surface would be of the same order.

The limits of penetration in a series of nickel steels are as follows :

Nickel, %	Temperature Limit of Penetration, ° C.
0	1620–1640
1	1600–1620
5	1600–1620
15	1620–1640

Nickel steels have been shown[10] to be more fluid than equivalent carbon steels in the range 0–6·0% of nickel. This can account for the lowering of the penetration limit by 20° C. with nickel contents of 1 and 5%. The raising of the limit with 15% of nickel cannot be explained.

The work on fluidity[10] already referred to has established that small additions of titanium reduce fluidity to a greater extent than any other element. This marked effect on fluidity is reflected in the raising of the penetration limit illustrated by the following results :

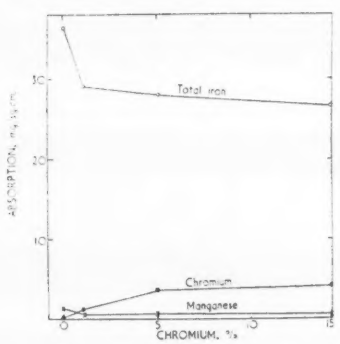


Fig. 21—Variation in absorption with varying percentages of chromium

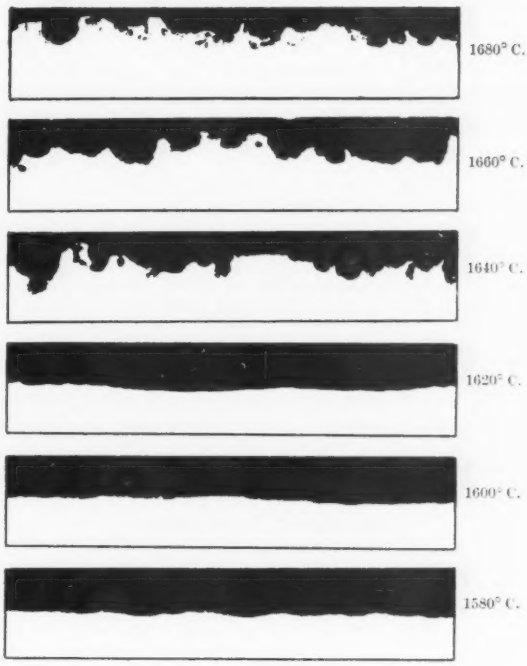


Fig. 22—Profile irregularities for Bentonite-bonded sand × 15 (reduced × ⅓ linear in reproduction)

Results Obtained from 0·16% Titanium Steel

Composition : 0·16% Ti, 0·28% C, 0·6% Mn, 0·31% Si, 0·032% S, 0·032% P

Casting Temp., ° C.	Average Depth of Profile Irregularities, mm.	State of Surface
1660	0·36	Adhering sand
1640	0·07	Smooth

CONCLUSIONS

The main conclusions from the work on the mechanism of sand adherence are as follows.

For a given mass of molten steel, metal penetration severe enough to cause sand adherence occurs suddenly within a temperature range of 20° C.

For a given composition, this incidence of penetration and adherence does not occur until a certain casting temperature is reached, and this temperature is different according to whether the moulding material is relatively coarse or fine.

Although the temperature limit of penetration is lowered as the grain size and permeability of the sand decrease, the actual depth of penetration is less with the fine-grained sands.

The critical temperature limit of penetration also depends on the composition of the steel. In general, elements which increase fluidity cause a lowering of the critical casting temperature. This is due to the fact that the casting temperature controls the sand/metal interface temperature. When this latter falls below the solidus, penetration is not severe enough to cause adherence. If this temperature falls above the solidus, adherence occurs.

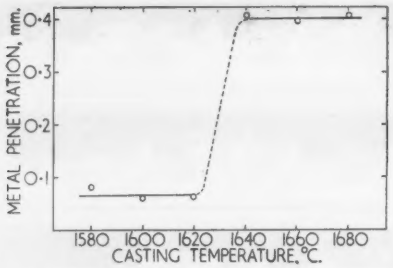


Fig. 23—Relationship between metal penetration and casting temperature for Bentonite-bonded sand

The reactions at the interface result in the formation of an iron silicate slag which does not affect penetration to any extent.

SAND ADHERENCE AS AFFECTED BY MOULDING MATERIALS

BONDING MATERIALS

Clay Bonds

In the first series of experiments concerning the effect of casting temperature, Arnold's No. 52 sand was bonded with Fulbond 3*A* (a synthetic sodium montmorillonite clay). Further experiments were conducted using the same sand, but with the natural sodium montmorillonite clay (Bentonite) as the bond. The results are given below, and the profile photographs are shown in Fig. 22 :

Variations in Penetration and State of Surface (Bentonite-Bonded Sand)

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
1680	0·40	Adhering sand
1660	0·39	,, ,,
1640	0·40	,, ,,
1620	0·06	Smooth
1600	0·06	,,
1580	0·08	,,

The metal-penetration graph, Fig. 23, shows the same sudden increase in penetration at the same temperature as when Fulbond was used. The above data, however, indicate that the depth of penetration is slightly greater in the case of Bentonite (*cf.* data on p. 144). The following chemical analysis of the sand aggregate from these castings shows that the alteration in bond does not affect the interface reactions :

Results Obtained from Analysis of Sand Aggregates (Bentonite-Bonded Sand)

Casting Temp., °C.	Ferrous Iron, mg./sq. cm.	Ferric Iron, mg./sq. cm.	Manganese, mg./sq. cm.
1580	35·2	2·81	1·08
1600	32·9	3·39	1·46
1620	34·7	3·14	1·03
1640	41·4	4·01	1·64

Cereal Binder

It is often stated that small additions of a cereal binder to the sand enhance the stripping qualities of the moulds. To ascertain the effect of such binders on the temperature limit of penetration, depth of penetration, and oxide absorption, a series of castings was made using the normal sand base and supplementing the 4% Bentonite with 1% G. B. Kordek (a starch-base binder).

The profile photographs are shown in Fig. 24 and the penetration graph (together with those of other bonding materials) is given in Fig. 25, which shows that the temperature limit of penetration is raised to between 1640° and 1660° C.

The results are as follows :

Variations in Penetration and State of Surface (Cereal-Bonded Sand)

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
1680	0·34	Adhering sand
1660	0·36	,, ,,
1640	0·11	Smooth
1620	0·12	,,

The casting stripped readily and the coherent sand aggregate was again formed. The results of the chemical analysis of the aggregate were as follows :

Results Obtained from Analysis of Sand Aggregates (Various Binders)

Binder	Ferrous Iron, mg./sq. cm.	Ferric Iron, mg./sq. cm.	Manganese, mg./sq. cm.
Starch	26·0	0·54	0·56
Ferric oxide	50·3	1·87	0·88
Portland cement	24·9	1·36	0·87

These results indicate that the reaction is somewhat reduced, as evidenced by a slightly lower percentage of reaction products. However, it is still sufficient to ensure the coagulation of the sand particles.

The raising of the temperature limit of penetration is probably due to a slight gas pressure set up in the pore spaces of the sand. Briggs and Morey[11] have demonstrated the considerable evolution of gas from cereal binders. Caine[5] suggested that the improvement is due to the formation of ' over-reduced ' steel of low fluidity as a result of the reducing atmosphere set up at the mould face. The effect, however, can be only a purely local one and it is difficult to account for any appreciable alteration in fluidity when the steel is fully deoxidized. The gas-pressure effect seems therefore the more likely explanation.

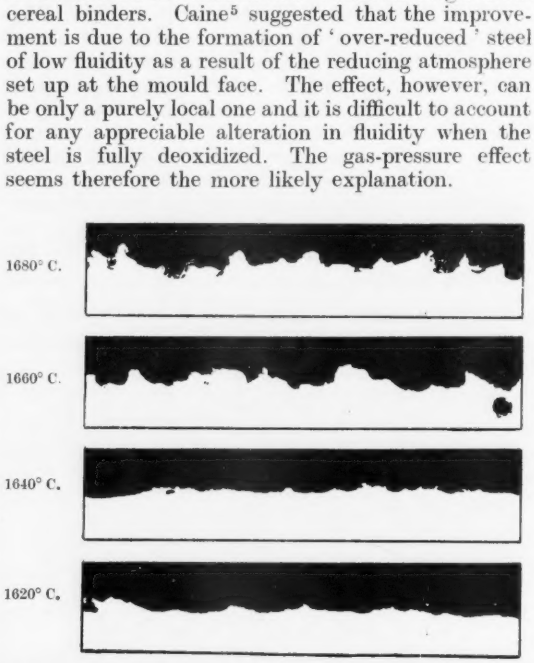


Fig. 24—Profile irregularities for cereal-bonded sand × 15 (reduced × 1½ linear in reproduction)

Oil Binder

For this series of experiments, the sand cores were rammed in the usual manner after milling for 4 min. with 4% of a semi-solid oil binder. The results are given below, the profile photographs are shown in Fig. 26, and the penetration graph in Fig. 25 :

Variations in Penetration and State of Surface (Oil-Bonded Sand)

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
1660	0·35	Adhering sand
1640	0·39	,, ,,
1620	0·35	,, ,,
1600	0·27	,, ,,
1580	0·22	,, ,,
1560	0·15	Slight adherence
1540	0·06	Smooth

Here the temperature limit of penetration occurs at 1560° C., which is 70° below that for the clay-bonded sands. The change is not nearly so sudden, as is indicated in Fig. 25, and another notable factor is the absence of the sand cake. On stripping, the sand crumbled readily as individual grains. An area assessment of slag absorption was impossible, but it was observed that the reaction had been much reduced. Only the surface grains showed signs of slag coating, and an analysis on some of these gave the following :

$$FeO\ 4{\cdot}2\%;\ Fe_2O_3\ 0{\cdot}10\%;\ MnO\ 0{\cdot}17\%$$

The effect of the linseed-oil-base binder is therefore the opposite of that of the cereal binder. The quantities used, however, were not strictly comparable, as they approximated to accepted standards.

It has been demonstrated that the temperature limit of penetration is reduced as the carbon content of the steel increases. It is probable that the liquid steel absorbs carbon from the binder and that, by lowering locally the solidification range, the increase in carbon tends to delay the formation of the solidified skin which prevents metal penetration. No positive explanation can be given for the gradual increase in penetration, as opposed to the normal sudden increase.

Ferric Oxide Bond

It is common practice to add ferric oxide to a synthetic sand to obtain the remarkable bonding properties found in a naturally bonding ferruginous sand. It is also claimed that the addition of ferric oxide enhances the stripping qualities.

It was impossible to procure a naturally bonding ferruginous sand of equivalent grain size to the ones employed in this research, and any other would invalidate comparison with the results already obtained. It is also realized that adding ferric oxide to a silica sand does not simulate exactly the conditions obtaining in a naturally bonding sand. However, experiments were conducted on a silica sand bonded with ferric oxide to give an indication of the effects to be expected from the use of a naturally bonding ferruginous sand. Replacing the Bentonite entirely with ferric oxide resulted in a sand with a too low green strength. The usual percentage of Bentonite was therefore retained and 5% ferric oxide was added.

The results are given below and in Figs. 25 and 27.

Variations in Penetration and State of Surface (Ferric-Oxide-Bonded Sand)

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
1660	0·47	Adhering sand
1640	0·38	,, ,,
1620	0·06	Smooth
1600	0·06	,,

The sudden occurrence of penetration and adherence again occurs between 1620° and 1640° C., the depths of penetration being similar to those encountered in the sand without the ferric oxide. Despite this, however, the sand was more difficult to remove because of its lack of friability, obviously associated with improved dry strength. Analysis of the aggre-

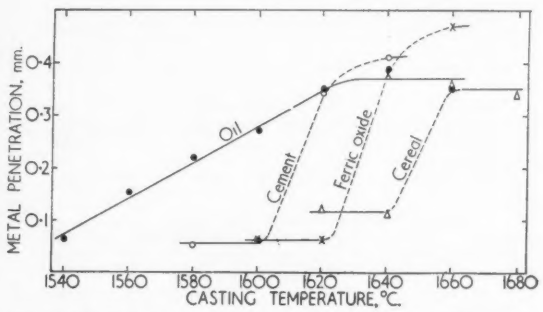


Fig. 25—Relation between metal penetration and casting temperature for various binders

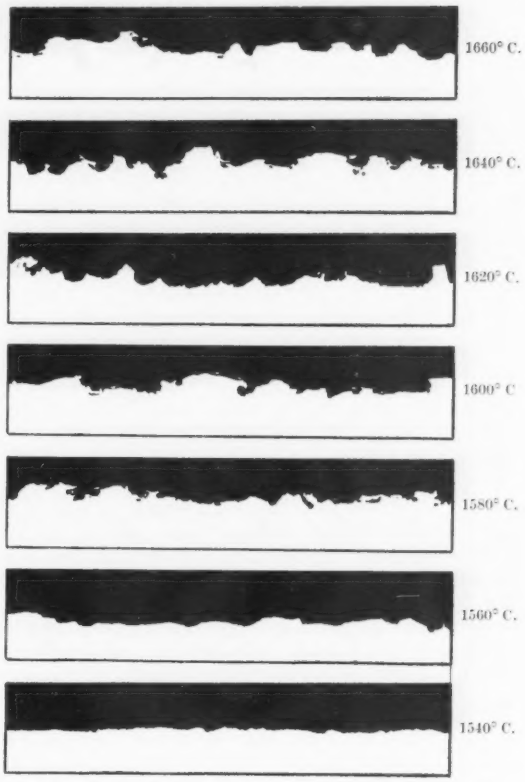


Fig. 26—Profile irregularities for oil-bonded sand × 15 (reduced × ½ linear in reproduction)

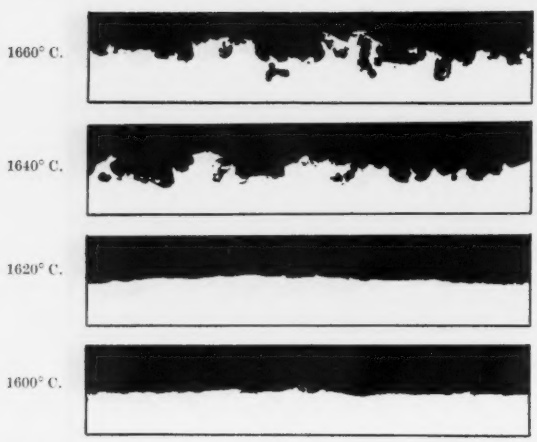


Fig. 27—Profile irregularities for ferric-oxide-bonded sand × 15 (reduced × ½ linear in reproduction)

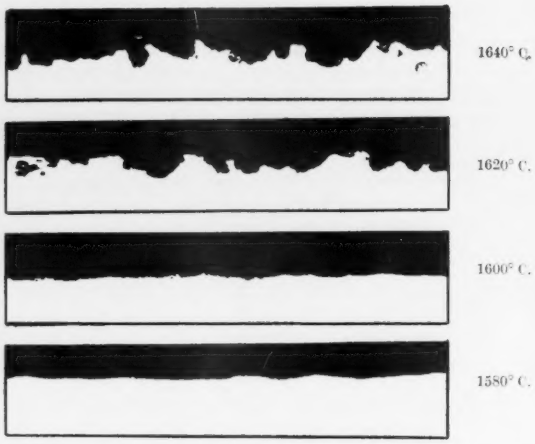


Fig. 28—Profile irregularities for cement-bonded sand

gate (already given) confirms that most of the iron was present as ferrous iron. Half the total iron present was due to the ferric oxide added so that the absorption value was approximately 26 mg./sq. cm.

Adding ferric oxide to a sand, therefore, does not aggravate burning-on, although its removal from internal angles might be more difficult.

Portland Cement

The results using the same silica sand bonded with 9·5% Portland cement and 4% water are given below and in Fig. 28 :

Variations in Penetration and State of Surface (Cement-Bonded Sand)

Casting Temp., °C.	Average Depth of Profile Irregularities, mm.	State of Surface
1640	0·41	Adhering sand
1620	0·34	,, ,,
1600	0·06	Smooth
1580	0·05	,,

The chemical analysis of the aggregate has already been given. The sand blocks were allowed to set for 72 hr. in air and were then dried under infra-red lamps.

Penetration sufficient to cause adherence occurs between 1600° and 1620° C. (Fig. 25), but the depths of penetration are similar to those encountered previously.

Oxide absorption is somewhat lower. As in the case of ferric oxide, the sand was more than usually difficult to remove because of higher mechanical strength.

EFFECT OF MOULD COATINGS

The relative merits of the various refractory materials used as paints are, in view of industry's endeavour to eliminate silica for health reasons, of paramount importance. It has been suggested that there is no satisfactory substitute for silica, but the following experiments show that some materials are, in fact, better. The materials investigated, together with the results and observations on stripping, are listed in Table VIII. Each paint was mixed under standard conditions into the same quantity of water, except in one or two instances where the required consistency could be obtained only by adding more water. Constant weights of bond materials, equal to 10% of the mixture, were used as follows :

Base	100 g.	Linseed oil	2·5 g.
Bentonite	5 g.	Water	85 g.
Starch	2·5 g.		

A constant volume of each paint was sprayed on to a block of sand to give approximately equal coat thicknesses. The blocks were allowed to air-dry before being dried for 1 hr. under infra-red lamps.

A casting temperature of 1680° C. was chosen, being a temperature at which adherence was known to occur. Those materials which proved unsatis-

Table VIII

VARIATIONS IN PENETRATION AND STRIPPING QUALITIES USING VARIOUS PAINTS

Base	Stripping Qualities	Average Depth of Profile Irregularities, mm.
Casting Temperature 1680° C.		
Corefrax	Very good peel, with oxide in thin surface layer	0·05
Fused alumina	,, ,, ,,	0·07
Sillimanite	,, ,, ,,	0·08
Zircon	,, ,, ,,	0·10
Pulverized aggregate	Peel with difficulty	0·11
Silica	,, ,, ,,	0·11
Plumbago	Very good peel	0·14
Ferric oxide	Strong adherence	0·52
Molochite	,, ,,	0·94
Olivine	,, ,,	0·98
Unpainted	Adhering sand	0·40
Casting Temperature 1640° C.		
Silica	Peel with difficulty	0·09
Plumbago	Very good peel	0·14
Ferric oxide	Strong adherence	0·57
Molochite	,, ,,	0·60
Olivine	,, ,,	0·62
Unpainted	Adhering sand	0·40

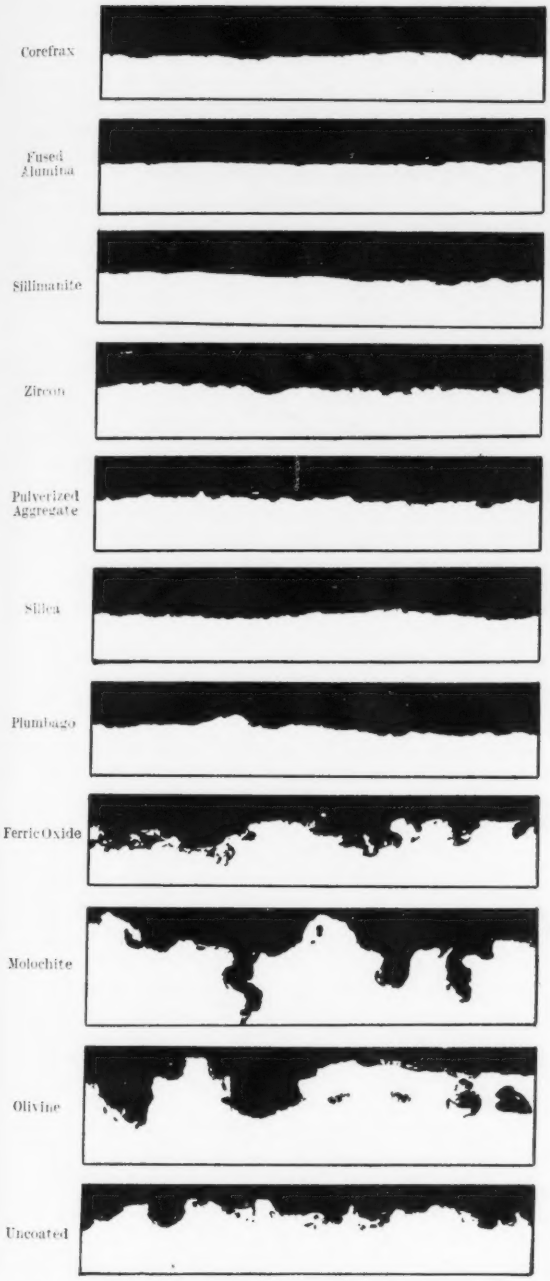


Fig. 29—Profile irregularities for various paints; casting temperature 1680° C.
× 15 (reduced × ½ linear in reproduction)

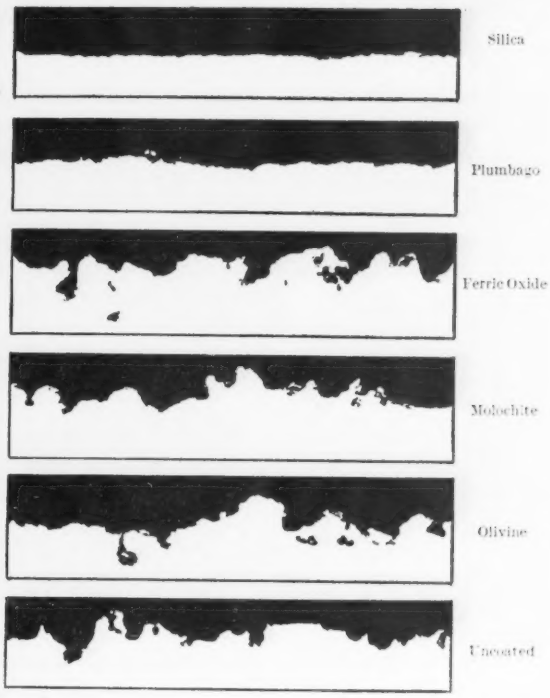


Fig. 30—Profile irregularities for various paints; casting temperature 1640° C.
× 15 (reduced × ½ linear in reproduction)

factory at 1680° C. were again tested at a casting temperature of 1640° C.

The profile photographs are shown in Fig. 29 for the series cast at 1680° C., and in Fig. 30 for the repeat trials at 1640° C.

Table VIII shows that the best results are obtained with Corefrax, closely followed by fused alumina, sillimanite, and zircon. Crushed aggregate and silica are about the same, giving average penetration values at this particular temperature equal to about twice that for Corefrax, and of a similar order to that for zircon. They did not, however, strip so readily as zircon. In the case of both silica and aggregate, there was evidence of oxide absorption and although the layers of sand adhered firmly to the casting, smooth surfaces were obtained once they were removed. The aggregate was obtained from previous castings, so that the presence of slag in the sand does not appear to offer any advantage over silica ; thus, if shot-blasting or any other mechanical method of cleaning is unavoidable, silica is quite satisfactory but compares unfavourably with Corefrax, alumina, sillimanite, and zircon for ease of stripping.

It will be observed (Fig. 32) that there is little oxide absorption in the case of Corefrax, the oxide being retained in a compact layer at the surface of the casting.

Plumbago gives easy stripping and good surfaces although, at the higher casting temperature, there is a tendency to obtain local metal penetration.

Other materials proved unsatisfactory at both casting temperatures. Olivine-coated moulds showed evidence of severe fusion with sand adherence and poor casting surfaces. This is probably the result of the reaction $Mg_2SiO_4 + SiO_2 = 2MgSiO_3$. The formation of this compound has been found to lower the fusion point of olivine by 300° C.[12]

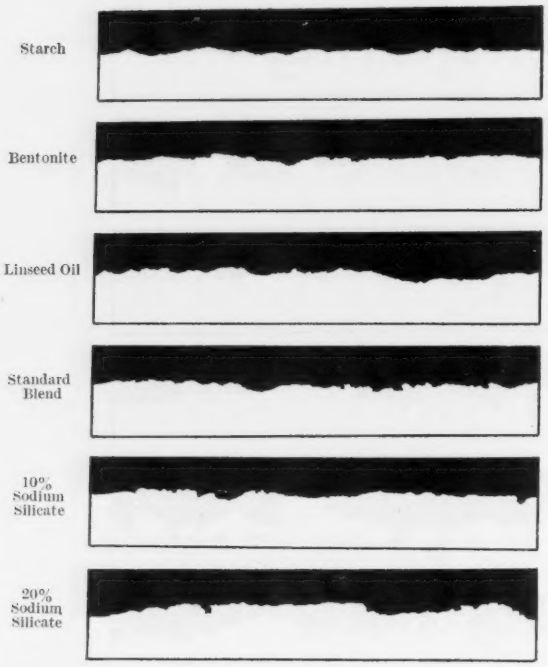


Fig. 31—Profile irregularities for various paint binders × 15 (reduced × ½ linear in reproduction)

Varying the bond material in the paints has very little effect, as evidenced by the results given in Table IX and by Fig. 31. For these experiments zircon was used as the base refractory and 10% of each binder was added, except in the case of sodium silicate where a higher percentage was necessary.

Apart from their effect on penetration, bonds in paints must be considered in relation to other requisite properties, such as absence of flaking on drying, surface stability, etc., and it appears that a suitable blend of the substances tried gives the best combination of properties. In fact, the proportions used in the standard paint did give a firm coating devoid of cracks, together with good stripping qualities and a good surface on the casting.

EXAMINATION OF SAMPLES FROM INDUSTRIAL CASTINGS

In view of the lightness of the standard casting used for this research it must be stated that actual results are applicable only to this particular casting, although the trends and theories will be true for any casting. Temperature limits of penetration, interface temperatures, fluidity, etc., will differ according to the mass of molten metal; ferrostatic pressure will also undoubtedly have an effect. This explains why the penetration and adherence was in no case as severe as is sometimes encountered in industry.

The following is an account of the examination of selected samples of severe ' burning-on ' from industrial castings. No data regarding casting temperature were available and the examination has been confined to an identification of the material and a probable cause for the ' burning-on.'

Superficial examination of the castings did not always confirm the presence of free metal, although its existence was frequently suspected from the shiny appearance after hammering. Sections of the specimens were prepared for micro-examination in the normal way and the specific gravity of the burnt-on material was determined.

Specimen No. 1 was chipped from a re-entrant angle in the interior of a heavy casting. The mould was made of ' compo ' and was faced with a thick coating of chamotte paint. General burning-on was not evident, but internal angles were very difficult to fettle.

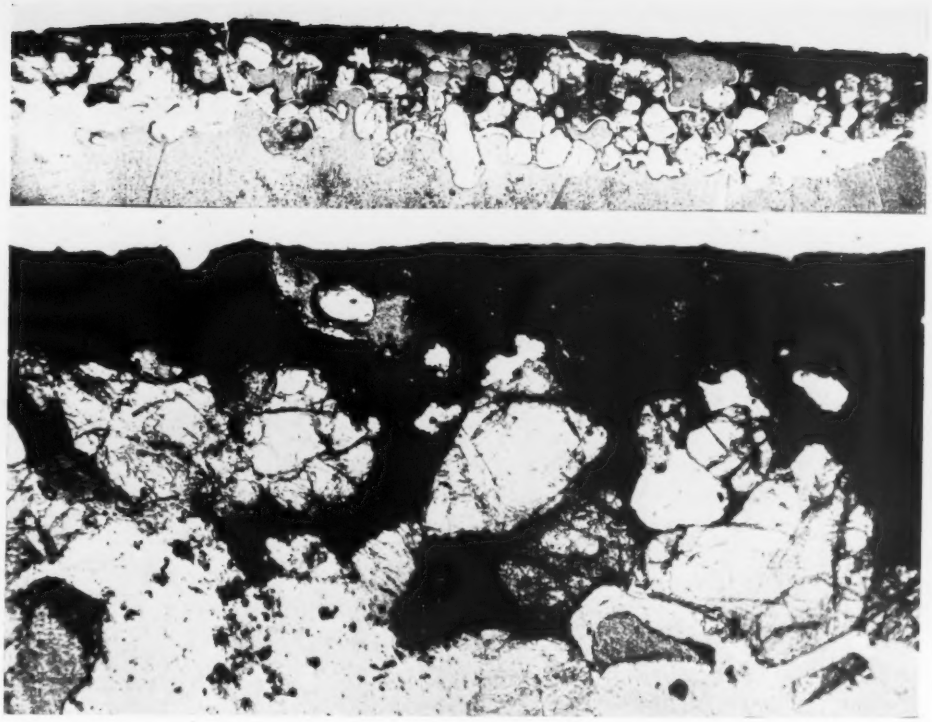
The specific gravity was 3·53, a figure greatly in excess of that of the moulding material itself. The photomicrographs are shown in Fig. 33. The light areas in the vertically illuminated photograph are metal; with oblique illumination, which shows up the sand grains better, this appears black. Micro-examination revealed an amorphous layer of material approximately ⅛ in. thick at one side of the specimen. The remainder consisted of individual grains of ' compo ' surrounded by a metallic network to a depth of from ¾ to 1 in. from the casting surface. The amorphous layer was free from steel and represented the chamotte wash which had been built up to a depth of ⅛ in.

The metal had obviously penetrated through a crack in the face into the relatively open-grained backing material. The filling of the voids would in such cases be facilitated by the high temperature attained by the ' compo ' as a result of its proximity to such a large volume of molten steel. The ease with which the metal flowed through the crack and into the voids would also be determined by the ferrostatic pressure from a 3-ft. head of liquid metal.

Table IX

VARIATIONS IN PENETRATION AND IN STRIPPING AND DRYING QUALITIES, USING VARIOUS PAINT BINDERS

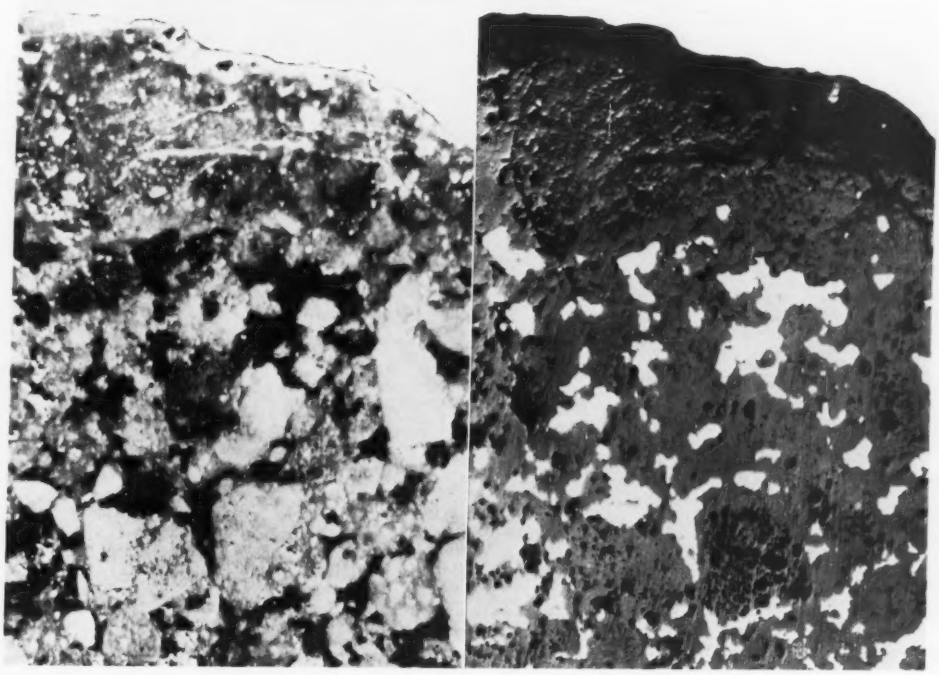
Bond	Drying Qualities	Stripping Qualities	Av. Depth of Profile Irregs., mm.
Starch	Hard surface, but cracks on drying	Very good peel	0·11
Bentonite	Powdery; small drying cracks	Good peel	0·12
Linseed oil	Soft; no cracks	Moderate peel	0·15
Standard blend	Hard surface; no cracks	Very good peel	0·10
10% Sodium silicate	Paint too thin	Moderate peel	0·11
20% Sodium silicate	Very hard, smooth surface	Good peel	0·11



(a) × 10

(b) × 40

Fig. 32—Section through sand aggregate from Corefrax-painted mould



Oblique illumination

Vertical illumination

Fig. 33—Section through burnt-on material (specimen No. 1) × 5

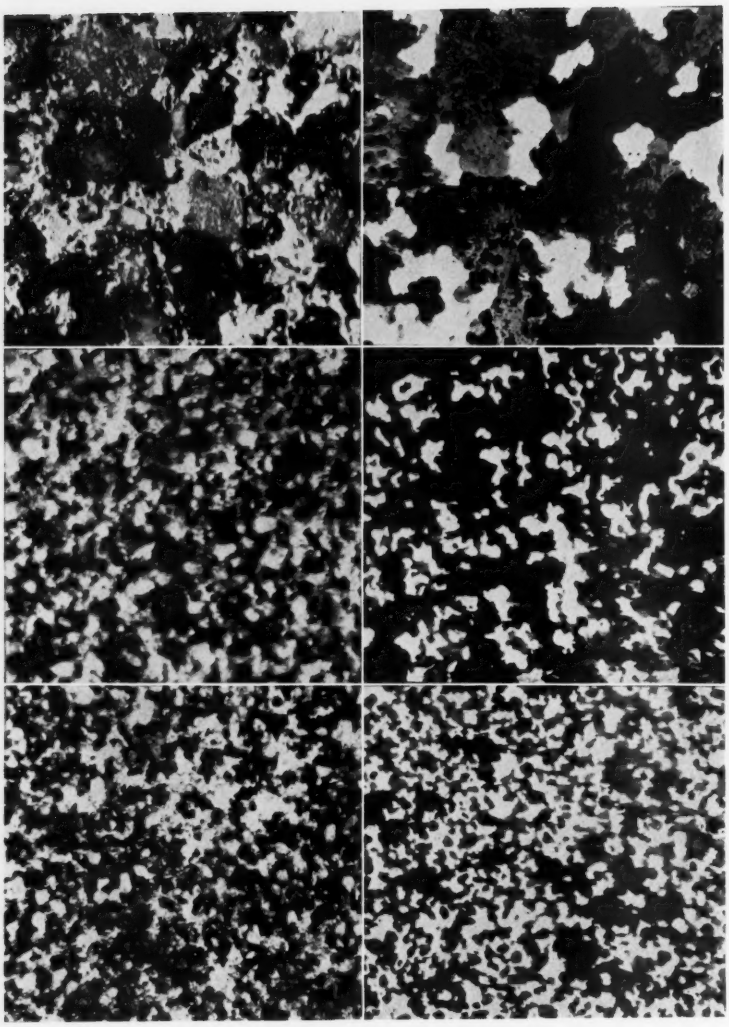


Fig. 34
(Specimen No. 2)

Fig. 35
(Specimen No. 3)

Fig. 36
(Specimen No. 4)

Oblique illumination

Vertical illumination

Figs. 34 to 36—Sections through burnt-on material × 5

Specimen No. 2, the photomicrographs of which are shown in Fig. 34, was taken from a heavy paper roll casting again moulded in 'compo.' In this instance, burning-on was general and a number of spoke-forming triangular cores could not be removed at all. The specific gravity of the burnt-on material was 3·80.

Specimen Nos. 3 *and* 4, Figs. 35 and 36, respectively, were obtained from similar tooth-pinioned castings, both moulded in a synthetic sand, No. 4 being a very fine-grained sand. Specimens were taken from between the teeth, and the specific gravities were 3·32 for No. 3 and 4·15 for No. 4.

In all these cases, the primary reason for the difficulty in fettling was metal penetration. In the case of No. 1, penetration was local and resulted from a crack or cracks in the mould face and was not due to the general fusion or breakdown of the granular constituents of the 'compo.' Initial cracking might have been due to some cause associated with drying, or as a result of thermal shock when pouring.

In the other cases, burning-on was general and resulted from the mass of metal, casting temperature, etc., giving the correct conditions for the particular metal composition being cast. As indicated by specimen Nos. 3 and 4, penetration is not confined to the more open-grained composition moulding materials.

Acknowledgments

The authors wish to record their appreciation of the helpful criticism and suggestions of their fellow research workers, Mr. J. M. Middleton and Mr. J. E. Worthington; also of Professor J. H. Andrew, and their thanks to him for his permission to use the facilities of the Metallurgical Department of Sheffield University, where the research was conducted. They thank the technical staff of that Department for assisting in the preparation of the moulds and the machining of the specimens. They also appreciate the help and encouragement of the Chairman, Mr. F. Cousans, and members of the Melting and Metallurgical Committee of B.I.S.R.A., who sponsored the research.

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Radioactive Indicators for Blast-Furnace Refractory Wear

By E. W. Voice, B.Sc., A.Inst.P.

SYNOPSIS

Some isotopes emit strongly penetrating gamma radiations which can be detected through two or three feet of firebrick. This property may be used to give evidence of blast-furnace refractory wear, and details of the method are given.

Blast-furnace refractories present special problems, in that they operate under arduous conditions of high temperature as well as under mechanical stress in very difficult chemical conditions. They cannot usually be inspected until many years after installation, and even then only the overall wear can be ascertained, little knowledge being obtained of the rate of wear. The refractories may scab over and form scaffolds, but so far there is no instrument that will measure this. Wearing away of refractories can, however, be detected by inserting radioactive pellets in two ways.

If a pellet of radioactive material can be inserted in the refractory sufficiently near to the shell for the radioactivity to be detected outside the furnace, the cessation of this activity would indicate that the pellet had been released and hence that the refractory in which it was embedded had been worn away. Alternatively, if the position of the refractory is too far from the shell of the blast-furnace to make detection through the wall practicable, conditions can be arranged so that, when the refractory wears away, the exposed pellet dissolves in the iron and can be detected when the iron is tapped.

Both methods are now being used in blast-furnaces in this country, and this paper sets out the considerations which have led to the present choice of materials and to the technique used.

Existing Installations

Seventeen pellets have been installed in four furnaces; positions chosen include behind the stack armouring, in the stack 15 ft. below the stockline, in

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Mr. Voice is in the Field Trials Section of the Iron Making Division of the Association.

the stack at lintel level, in the brickwork between slag and metal notch, and in the tap-hole roof.

Size of Pellet

When held or sealed in alumina or silica, the overall size of a pellet is about that of a sugar lump ; hence the pellets can be inserted easily into bricks, or similar materials, without causing appreciable damage or weakening of the brick.

SPECIAL PROPERTIES OF RADIOACTIVE MATERIALS

Many substances, when bombarded by neutrons, form unstable isotopes which disintegrate and produce new isotopes. During these processes they emit α, β, or γ radiations at a constant rate for a given number of atoms, independent of temperature or pressure.

Half-Life

The rate of disintegration varies with the isotope, and may continue for only fractions of a second or for thousands of years : a measure of the rate of disintegration of an isotope can be obtained from tables of half-life. If an element has a half-life of 5·3 years (as for cobalt 60) then, for a given quantity, the radioactivity will be half as much after 5·3 years, a quarter as much after 10·6 years, one sixteenth as much after 21·2 years, and so on, independent of the temperature of the element or whether it forms any compounds. Wherever the active cobalt atoms are, they will disintegrate at this rate.

Radiation Emitted

α-particles are charged helium nuclei, and have very low penetration powers ; one or two inches of air are enough to absorb them.

β-particles are electrons, also of low penetrating power ; a sheet of paper or glass is enough to absorb most of them.

γ-rays are similar to X-rays, and have great powers of penetration.

Neutrons are uncharged sub-atomic particles with great powers of penetration. No simple isotope gives off neutrons spontaneously, and it is unlikely that there is a convenient source which could be used for blast-furnace work.

Choice of Material

If a γ-source is alloyed in, say, a mass of pig iron, enough γ-rays can escape from the iron to indicate the presence of the source behind a large thickness of refractory. In practice, therefore, a γ-source is the most suitable, and cobalt 60 has been chosen. With a half-life of 5·3 years, it emits γ-rays of 1·1 and 1·3 million electron volts (m.e.v.) and has a high excitation cross-section. This means that it lasts a long time and gives a strongly penetrating radiation, and in addition it may be quickly produced from ordinary cobalt in the Harwell Atomic Energy Pile. Other advantages are that it has a high melting point, and will alloy easily with iron.

Detection

Portable or mains-operated counters are available to detect the radiations emitted. Counters always give a reading as a result of cosmic ray activity, etc., but if the intensity to be measured is ten times this normal background, then detection should be possible for 5–10 years. An intensity 30 or 40 times as great can still be regarded as safe for a person to remain continuously exposed to the radiation.

Appendix I gives the absorption coefficients, from which it is possible to calculate approximately the intensity required to give the activity at given distances, allowing for the material between source and counter.

APPLICATION TO BLAST-FURNACE PROBLEMS

In the stack, bosh, or tuyere belt of a blast-furnace the counter can be brought to within two to three feet of a cobalt pellet embedded in the lining. But in the hearth the counter cannot be brought near enough to detect the radioactivity of a quantity of cobalt small enough to be harmless if absorbed by the iron ; in this case the mains-operated counter would be used. Samples would be kept of each cast, and by presenting the samples to a counter (weeks after tapping if necessary) it should be possible to detect which samples show radioactivity and hence when the pellet was detached from the hearth and dissolved in the iron.

PROPERTIES OF COBALT 60 FOR OBSERVATION OF STACK WEAR

Pellets of cobalt 60, 6 mm. long × 6 mm. dia., weighing about 1·6 grams, can be irradiated in 2–3 weeks to produce an activity of 10 millicuries (mc.). By leaving them in the pile for longer periods, pellets become more active. The radioactivity at given distances from a pellet varies inversely as the square of the distance, and varies exponentially according to the absorption coefficient of the materials between the source and counter. Enough activity is required at the shell of the furnace for detection to be possible, but there is no point in using more than is necessary.

Calculations show that an activity of 10 mc. can be detected through, say, 2 ft. of firebrick or carbon, 6 in. of ramming, and $\frac{1}{2}$ in. of mild steel plate shell. For every extra 6 in. of brick the source should be trebled, so that 90 mc. would be necessary if 3 ft. of firebrick or carbon is used.

The melting point of cobalt is 1490° C., and its vapour pressure is low for most positions in the stack brickwork. However, if chemical attack takes place on the cobalt, it is easily possible that the pellet will no longer stay in position, and it might be wrong to deduce from its absence that the brickwork had worn back to this point; for this reason methods of wrapping the cobalt in sealed containers have been considered. Certain problems arise in choosing suitable containers. Ideally, they should be impervious to gas penetration and cobalt vapour, and yet should disintegrate quickly when in contact with molten slag or metal. If disintegration is slow, it is possible that the container will be released when the brick wears away, and may remain as a discrete lump in the metal or slag. Care must therefore be taken to prevent this, and to ensure that the quantities used are safe when alloyed with the iron, no matter for what purpose the iron is used. Appendix II gives results of experiments and calculations to show how much

activity can be used with safety; it is this aspect that sets a limit to the quantities that should be used.

Pellets sealed *in vacuo* in fused silica tubes were tried. These are unlikely to be satisfactory when used much above 1000° C., because the silica would tend to craze and would lose its protecting properties. Silica-wrapped pellets were used on one furnace in the upper stack, but it is not yet possible to say whether they are really satisfactory.

Fused alumina is probably the best material for high temperature, but to obtain an impervious wrapping it is necessary to use recrystallized alumina, which will withstand a temperature of more than 1600° C. Sealed 'triangle RR' crucibles are of this type and appear to be excellent. In a reducing atmosphere they have withstood heating for three weeks at 1600° C. without any detectable change. Unfortunately, the material is so refractory it is possible that the crucibles might take some hours to break up in the molten slag in the hearth. They should, however, break up fairly readily in passing through the tuyere zone. For this reason doubts have been expressed about using sealed alumina pellets lower down than the slag notch, in case the pellets come out of the furnace in their original form. Where pellets are subject to abrasion in the stack and then pass through the tuyere zone, it is reasonable to expect that they will break up; these sealed pellets could therefore be used.

Experiments are being carried out using cobalt in unsealed alumina crucibles in a carbon brick. These will be heated in a laboratory furnace to 1500° C., and the change in weight and loss of radioactivity will be measured with the passage of time. If the results are satisfactory it will be worth while using this form of wrapping in the furnaces. Some unsealed sources have been installed in one furnace stack, but it is too early to know how well they last.*

PROPERTIES OF COBALT 60 FOR OBSERVATION OF HEARTH-BRICK WEAR

Appendix I indicates that a large amount of activity would be necessary if a pellet put in the centre of a blast-furnace hearth is to be detectable from outside. Appendix II indicates that if such an amount of cobalt is added to the metal, this would become too active for unrestricted sale. If, however, a pellet were put in a brick in the hearth, the pellet would be released on subsequent wear, and the cobalt would alloy with the metal. The metal would then become radioactive, and samples of each cast could be stored and placed near to a counter at, say, weekly intervals; the amount of activity required would be just enough to obtain a count from the metal. Also, in view of the sensitivity of the counter, the amount would not make the metal objectionable. An activity of 20 mc. in 100 tons of metal is easily detectable with a sensitive counter, and the metal is perfectly safe, even when used for carriers for photographic films (*see* Appendix II). Such a pellet in this position will be at a high temperature for a long period, so care must be taken that it does not evaporate. Equally, if it is in a sealed alumina crucible it may float to the slag when released, and may come out of the slag notch before it disintegrates.

It is possible, but unlikely, that when released the pellet might go downwards into the hearth floor and linger there. In this case it is almost certain to be diluted with iron, so it should not be a nuisance when the furnace is blown out—in any case its presence could then be detected by a probe counter. Evidence on this question should be provided by the results of a forthcoming experiment where unsealed cobalt 60 is to be put into a brick in the protective firebrick lining laid on a carbon hearth. These bricks are expected to last only a few days: if the activity does reach the metal as anticipated, then it is unlikely that all the cobalt would go downwards.

If this experiment is satisfactory, and if the use of unsealed cobalt appears suitable from laboratory results, it is suggested that pellets should be tried in the top centre brick of carbon and firebrick hearths.

SAFETY IN HANDLING

It is safe to be within 1 ft. of a bare source of 10 mc. for 4 hours per week, but the protection afforded by 1 ft. of brick or 2 in. of steel plate is considerable. The normal safety technique adopted is to fit the pellets in the lining and to build a stack of three or four loose bricks in front of them while the furnace is being bricked. These come away when the scaffolding is removed. If is, of course, perfectly safe everywhere outside the furnace.

CONCLUSION

A good start has been made in initial installations, the results of which should indicate whether or not the technique gives useful information.

Although knowledge of brick wear or failure may give rise to problems earlier than expected, it is thought to be a necessary preliminary in increasing understanding of the problems of furnace linings.

Acknowledgments

Assistance with development of the technique is gratefully acknowledged to the Ministry of Supply (Atomic Energy Research Establishment), and the author also thanks the Morgan Crucible Co., Ltd., for supplying 'triangle RR' crucibles.

APPENDIX I

Absorption Coefficients

10 mc. of cobalt 60 will give an intensity of 100 mr./8 hr. in air at a distance of 3 ft. This is equal to an intensity of about 1400 times background. The intensity varies inversely with the square of the distance; therefore, if the source is, say, $2\frac{1}{2}$ ft. from the counter, the intensity will be:

$$1400 \times \frac{3^2}{2\frac{1}{2}^2} = 1400 \times \frac{9}{6\frac{1}{4}} = 2000 \text{ times background.}$$

The intensity at a point distant from the source will also be reduced owing to absorption by the medium between source and counter. The absorption in air is negligible, but that in bricks and steel is appreciable.

*Preliminary results made available after the receipt of the MS. are given in Appendix III.

The relation between intensity and absorption is given by the following formula:

$$i = i_o e^{-\mu t},$$

where i = intensity obtained
i_o = intensity without absorption
μ = absorption coefficient, per cm.
t = thickness, cm.

B.I.S.R.A. have determined the values of μ for typical materials used in a blast-furnace. Results obtained are as follows:

Material	μ (Probable error $\geqslant$ 10%)
Large coke	0·014
Small coke	0·018
Sinter	0·053
Slag (−½ in.)	0·038
Firebrick	0·060
Mild-steel plate	0·35
Carbon blocks	0·060
Northants ore (−½ in.)	0·055

If the distance from source to counter is 2½ ft., using 10 mc., then $i_o = 2000 \times$ background. If the medium is 2 ft. (60·96 cm.) of firebrick, 4 in. (10·16 cm.) of ramming, 1 in. of air, and 1 in. (2·54 cm.) of mild steel, then:

$$i = 2000e^{-\{60\cdot96 \times 0\cdot06 + 10\cdot16 \times 0\cdot04 + 2\cdot54 \times 0\cdot35\}}$$
(assuming $\mu = 0\cdot04$ for ramming)
$$= 2000e^{-4\cdot96}$$
$$= 14 \times \text{background.}$$

This would give a reasonable count, even after 5 or 10 years. Every further 6-in. increase of brick thickness reduces the intensity to about one third; *i.e.*, 12 in. extra thickness reduces the intensity to one ninth, approximately.

APPENDIX II

Cobalt 60 in Iron : Permissible Quantities for Safe Use

Discussions took place at A.E.R.E., Harwell, in January, 1950, to estimate how much activity can be added to production iron without causing trouble. It was agreed to take as the limit the condition that, if the final steel is adjacent to a fast X-ray film, the storage life of the film should not be more than halved.

With a γ-counter of area 20 sq. cm. adjacent to the metal, and a counter efficiency of 3% for cobalt 60 rays, a count of not more than 30/sec. would be obtained (*i.e.*, five times normal background). Therefore the count given off by the metal backing plate

$$= 30 \times \frac{100}{3} \times 2 \text{ disintegrations/sec.}$$
(× 2 because only half penetrates the plate; *i.e.*, back and front radiation)
$$= 30 \times \frac{100}{3} \times 2 \times \frac{1}{20} \text{ disintegrations/sq. cm./sec.}$$
$$= 100 \text{ disintegrations/sq. cm./sec.}$$

Assume density of iron = 8 g./c.c.

Then tolerance for metal 1 cm. thick = 12·5 disintegrations/sec./g. (ignoring self-absorption).

Quantity of cobalt 60 (mc./100 tons) to give this tolerance

$$= \frac{(100 \times 2240 \times 456) \times 12\cdot5}{3\cdot7 \times 10^7}$$
$$= 34 \text{ mc./100 tons.}$$

If the hearth capacity is 150 tons of metal, and if 20 mc. are used, the activity = 13·4 mc./100 tons. Therefore, a tolerance of 1 is obtained by placing a photographic plate against a pig-iron plate 34/13·4 cm. (= 1 in.) thick. If the metal is diluted in a mixer, 5 to 1, and if scrap additions in the open hearth are 40%, then the permissible thickness = 7 in.

Summarizing, if 20 mc. of cobalt 60 are added to 150 tons of hot metal (used for steelmaking as in the above sequence), a photographic plate can be stored safely against a 7-in. thickness of metal.

The greatest chance of damage appears to be in the case of a plate stored against a girder. But if the girder were, say, ½ in. thick, it would probably be bricked in. A ¼-in. thickness of steel is probably the maximum thickness to be met in practice, and the margin of safety would then be 28 to 1. This means that the shelf life of the film would be reduced by less than ½ × (1 in 28), *i.e.*, less than 2% (or 12% if the metal is not diluted by steelmaking).

Detection—When detecting pig iron, using 20 mc./150 tons, a sample 1 in. thick would be necessary for a count of 5 × background (desirable in view of 5-year half-life). Using a scintillation counter under good conditions, a few grams would suffice.

Experiment—The management of Park Gate Iron and Steel Co., Ltd., kindly allowed B.I.S.R.A. to add 1 mc. of cobalt 60 to 18 tons 6 cwt. of hot metal in a ladle. Spoon samples taken at the beginning, middle, and end of pouring out the metal showed the anticipated count, and all three samples were identical, showing that the cobalt became evenly alloyed in the entire mass of metal.

APPENDIX III—Evaporation of Cobalt at 1550° C.

By T. E. Dancy, Ph.D., D.I.C., A.R.C.S.

In some applications it was desirable that totally enclosed cobalt pellets should not be used, especially if it were necessary for the released cobalt to pass rapidly into the metal without the risk of the capsule floating up into the slag and passing out of the furnace as a discrete whole (*e.g.*, use in the hearth). Since no accurate data were available on the rate of evaporation of cobalt at about 1550° C., some laboratory experiments were made under similar conditions to those expected in the blast-furnace.

Small rates of evaporation, which were expected over the comparatively short duration of laboratory experiments, could not be followed by weighing. Weight alterations could easily occur, owing to contamination of the cobalt by the refractory container or by carbon pick-up. Therefore a radio-active counting technique was used, which could be made

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Table I

VARIATION OF COBALT COUNTS WITH HEATING TIME

Heat No.	Time of Heating at 1550° C., hr.	Counts/min. (Corrected for Background) Co Pellet	1 μc. Standard	Co Pellet*
0	0	8069±17	3285±8	8069
1	234	7507±20	3050±11	8085
2	359	7475±27	3128±12	7850
3	508	7512±25	3075±9	8025
		11,218±16†	3142±12	
4	744	11,284±22†	3129±10	8041

* Calculated on the basis of 1 μc. source at zero time
† Improved method of mounting

sufficiently accurate to follow significant changes in the amount of cobalt present.

Experimental

A 1·6-g. pellet of inactive cobalt was melted with a small quantity of the active isotope, giving an activity of about 5 μc. in the product. The emission from this pellet was counted by mounting the cobalt in a clamp which was accurately positioned with regard to a Geiger-Müller counter. A number of 5-minute counts were made alternately with those of a standard 1-μc. source of cobalt 60, and checks on the background. A statistical error of less than 0·3% was obtained. After counting, the pellet was placed in a small 'triangle RR' crucible, with a loosely fitting lid temporarily held in place by platinum wire, and the crucible was rested in a hole in a carbon block and was covered with graphite powder. The block was placed in an alumina tube, through which a slow stream of nitrogen (0·4% of O_2) was passed, and was heated to 1550° C. in a molybdenum furnace.

The activity of the pellet was determined after each heating (*see* Table I), the pellets being mounted in an identical fashion in every case; the counter was checked each time by means of the standard source, and therefore allowance could be made for the natural decay of the cobalt 60.

Results

Table I shows that the counts/min. from the cobalt pellet show a scarcely significant drop after 744 hr. at 1550° C. The accuracy of the count after heat No. 2 is questionable, as can be seen from Fig. 1. It was unlikely that this drop in activity was real, because after each heat the tube, the graphite block, and the gas outlet bubbler were tested for activity, and in no case was a significant activity detected. Therefore, if this point is ignored, the 'best line' through the remaining four points has a negative slope of 0·1 counts/min. after 1 hr. at 1550° C. This represents $\frac{0{\cdot}1}{8095} \times 1{\cdot}6$ g. of cobalt lost per hour; therefore, assuming the evaporation continues to the end at the same rate, evaporation of the whole pellet takes place in $\frac{8095 \times 1{\cdot}6}{1{\cdot}6 \times 24 \times 0{\cdot}1}$ days, *i.e.*, 9·24 years. This rate may be considered a maximum, as these experiments were conducted in a stream of gas. When a pellet is used in a brick in a blast-furnace it is unlikely that there will be a flow of gas outside the hole, since there will always be another brick adjacent to the one in which the pellet is embedded. Also, the temperature inside a hearth brick probably will not be higher than 1550° C.

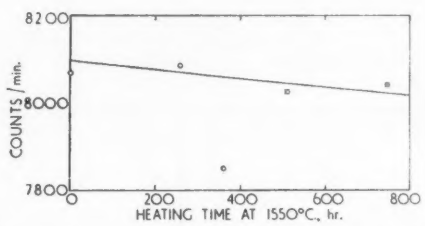


Fig. 1—Variation of counts from cobalt pellet with time of heating

Theoretical Calculation

The rate of evaporation from 1 sq. cm. of surface of cobalt at 1550° C. is 8×10^{-8} g./sec. under atmospheric pressure, assuming that the cobalt is enclosed in an impervious pot with a hole of area 1 sq. mm. within 0·5 cm. of the surface. This would allow 1·6 g. to evaporate in about 60 years, assuming the evaporation continued at a constant rate. The vapour pressure of cobalt was taken as 0·1 mm. of Hg at 1550° C., and the collision diameter of Co–N_2 was assumed to be $\frac{4}{3}$ × collision diameter of N_2–N_2.

Conclusion

From the results it seems probable that cobalt pellets, when placed in unsealed alumina crucibles in the hotter regions of blast-furnace brickwork, may remain in sufficient quantity for adequate detection for a number of years, provided that the brickwork remains intact.

Acknowledgments

The author thanks C. B. Alcock for assistance in the radio-active counting, and H. Herne for the theoretical calculation.

N.P.L. Electronic Brain

A pilot model of the Automatic Computing Engine (ACE) is now working at the National Physical Laboratory, D.S.I.R., where it has been designed and constructed. The ACE itself will be built later but the pilot model is a complete computer. The computer, popularly known as an 'electronic brain,' has already been used for solving some problems, and the Superintendent of the Mathematics Division, N.P.L., will be glad to hear of industrial problems whose solving requires lengthy and intricate arithmetical calculations.

Much has been learnt in the building of the pilot model and it is clear that use and improvement will go hand in hand for some years. The ACE itself, for example, will be improved in reliability by the re-design of certain parts, it will be faster and its memory capacity will be greatly increased by the addition of an auxiliary magnetic recording storage system.

The ACE is extremely versatile. Unlike some similar types of machine which are built to deal with one recurring problem only, the ACE can be made to tackle any problem requiring arithmetical calculation. All mathematical calculations in the end resolve themselves into addition, subtraction, multiplication, and division, so that for practical purposes there is no limit to what the ACE can do in this field.

Ringing in Wire-Drawing Dies

By J. G. Wistreich

SYNOPSIS

'Ringing,' which is a form of grooving of dies near the point of entry of the wire, is an undesirable phenomenon, the suppression of which might result in better die performance. It is concluded from experiments that, generally, ringing is not caused by the abrasive action of a contaminated lubricant, but is the result of the steep stress gradient at the beginning of the working surface of the die. For this reason ringing cannot be altogether suppressed, but it is possible greatly to reduce its severity by applying heavy back pull to the wire.

Introduction

'RING' is a term given to the circular groove which appears in a die as the result of wear, close to the place at which the wire makes contact with the die wall; it is present in every worn die, whatever material it is made of. It is not known whether the ring itself is harmful, but it leads to roughness and longitudinal grooving of the working surface of the die, and this causes ridges to appear on the wire.[1] A worn die is re-serviced by lapping and polishing; the deeper the ring, the greater the amount of material that must be removed before smoothness of the profile is restored. Moreover, the deeper the ring, the more the bore of the die must be enlarged, and consequently the total useful life of the die is shortened.[2] Ringing, therefore, is an undesirable phenomenon, and its suppression or mitigation can improve die performance and machine output.[3]

Two alternative hypotheses on the causes of ringing have been put forward. One suggests that hard particles of dust, lime, or other contaminating matter borne by the lubricant, abrade the die surface in the pocket between the die and the incoming wire.[4] The other assumes that a steep stress gradient exists in the die wall adjacent to the point where the plastic deformation of the wire is initiated, causing failure of the die material.[5] The choice between the two hypotheses should not be difficult, once the position of the ring relative to the point of contact between wire and die has been accurately determined. For, if the first supposition is true, the ring should *end* at the point of contact; on the other hand, should it be found that the point of contact marks the *beginning* of the ring or occurs just inside it, then the second hypothesis is more likely to be the correct one.

The second hypothesis might be tested in a different fashion by observing whether ringing is in any way affected by a change in the stress system. The stress in the working surface of the die at the point of entry is such that the wire is brought to the plastic state, so that, without tension in the incoming wire, the die stress at that point is approximately equal to the yield stress of the wire. If back pull is now applied, this stress will be reduced in proportion to the tensile stress already existing in the wire at the moment it hits the die wall.

These tests are difficult to perform, because a considerable length of wire (more than 10 miles[1]) has to be drawn through a die of the kind generally used, before the ring is measurable, and variations in diameter are inevitable in such a length of commercially produced wire. Also, since the angle between wire and die is usually only a few degrees, a small uncertainty about the diameter of the wire makes the position of the point of contact indeterminate. Another practical difficulty is that, normally, the wire enters the die freely, and contact with the die changes from point to point with the vibrations and curvature of the wire.

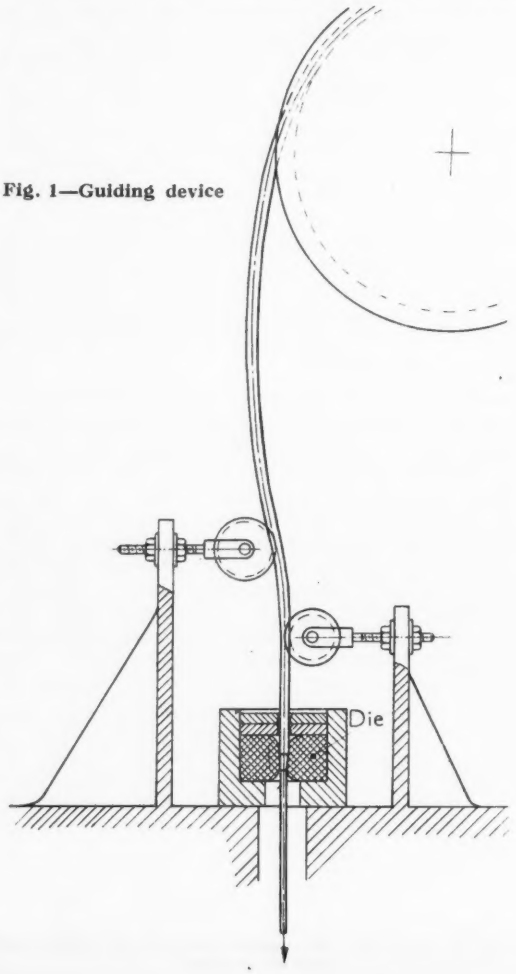


Fig. 1—Guiding device

Paper MW/D/30/50 of the Drawing Committee of the Mechanical Working Division of the British Iron and Steel Research Association, received 23rd August, 1950. The views expressed are the author's and are not necessarily endorsed by the Committee as a body.

Mr. Wistreich is Head of the Drawing Section of the Mechanical Working Division of the Association.

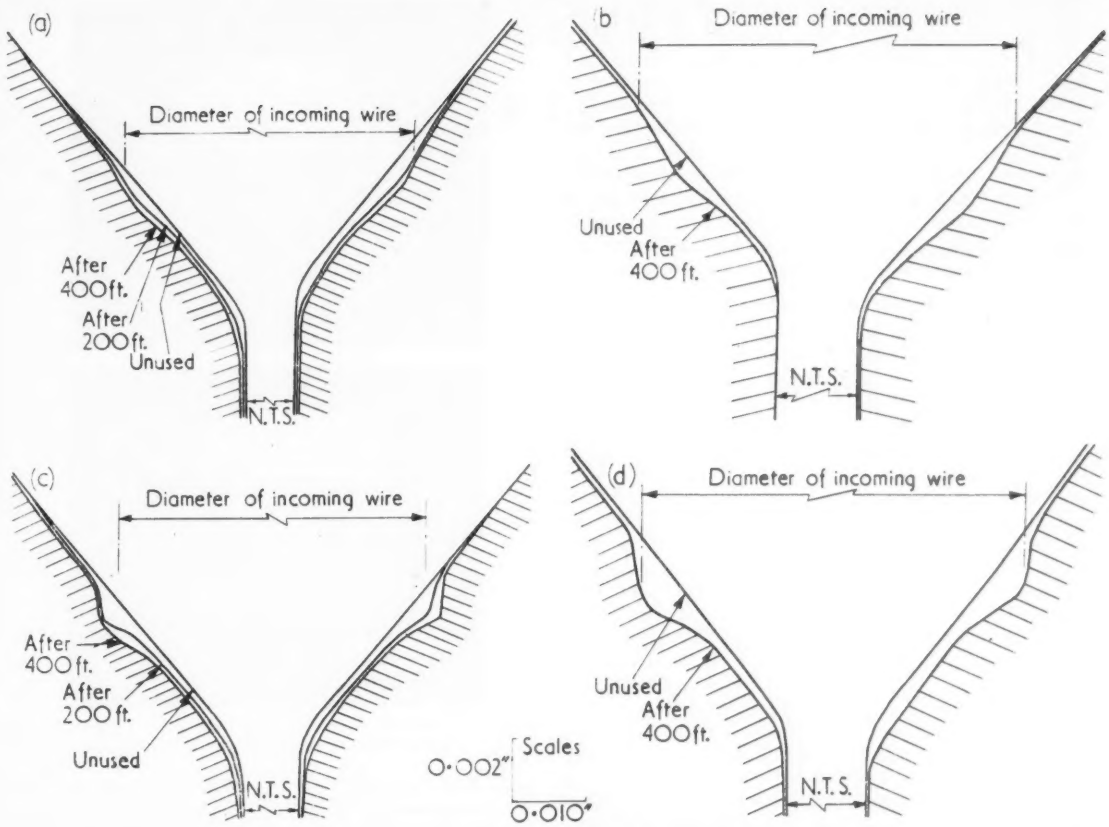


Fig. 2—Profiles of dies: (*a*) Die *A*, with back pull ; (*b*) die *B*, without back pull ; (*c*) die *C*, with back pull ; (*d*) die *D*, without back pull

In the experiments described in this paper, these difficulties were overcome by the use of steel dies, by drawing very slowly, and by carefully guiding the wire. The steel dies were found to wear so rapidly that the ring was discernible after 50 ft. of wire had been drawn through ; 400 ft. of wire sufficed for each experiment. The size of the wire could thus, without difficulty, be maintained constant to within less than 0·0001 in. The drawing was accomplished on a machine especially constructed for experiments of this kind, and the tendency of the wire to enter the die obliquely[2] was counteracted by constraining it in the manner shown in Fig. 1. Finally, care was exercised with the wire and lubricant, so as to exclude, as far as possible, the risk of introducing abrasive matter.

EXPERIMENTAL DETAILS

Four dies were selected from a batch made from a piece of high-carbon steel bar, and were heat-treated together, precision ground, and lightly polished, so that they were similar in respect of hardness, surface finish, and die angle as the following figures show :

Die	Die Angle	Hardness, V.P.N.	Bore Size, in.
A	19° 5′	682	0·0717
B	19° 25′	715	0·0717
C	19° 52′	795	0·0716
D	17° 5′	725	0·0716

In the first experiment, two lots of bright, soft, electrolytic copper wire (0·092 in. dia., 16·3 tons/sq. in. ultimate tensile strength) were drawn through a sintered carbide die (to 0·0795 in. dia., 22·8 tons/sq. in. ultimate tensile strength), and then one lot was drawn through die *A*, the other through die *B*, at a finishing speed of 20 ft./min. The profiles of both dies were measured on the B.I.S.R.A. Profilometer[6] before use, and after 200 ft. and 400 ft. of wire had been drawn through them. The two tests differed as follows :

In the first test, die *A* was placed in tandem with the sintered die, so that the two passes were achieved simultaneously. Consequently the wire entering die *A* was stressed by the amount needed to draw it through the sintered die. The total drawing force was 182 lb. In the second test, the wire was drawn separately through the sintered die, and then through die *B*, so that it entered the experimental die freely. The drawing force for the sintered die was 140 lb., and for die *B* was 102 lb. It follows from the force measurements that die *A* worked with a back pull of 140 lb. and that the die load was 182 − 140 = 42 lb.

A similar experiment was performed with dies *C* and *D*, using mild steel wire, drawn 11% from the annealed state, instead of copper wire. Back pull was applied to die *C* by passing the wire over a braked drum. The back pull amounted to 155 lb., and the drawing force was 237 lb.; the load on the die was therefore 237 − 155 = 82 lb. No back pull was applied to die *D*, and the load on this die was 138 lb.

The results of these experiments are summarized in Fig. 2, in which typical traverses of the die profiles indicate the shape of the ring; in Figs. 3*a* and *b* the surfaces of two of the worn dies can be studied.

DISCUSSION OF RESULTS

It is apparent from these experiments that back pull exerts a profound effect on ringing. Without back pull the ring is both deeper and sharper in outline than with back pull; in the first case it is cylindrical in shape and is of approximately the same size as the incoming wire, in the second case the change in the slope of the die wall is small and gradual. One may conclude from this that, normally, the wire does not at first deform plastically but cuts into the die, whereas, if drawn with back pull, it begins to deform as soon as it strikes the die wall.

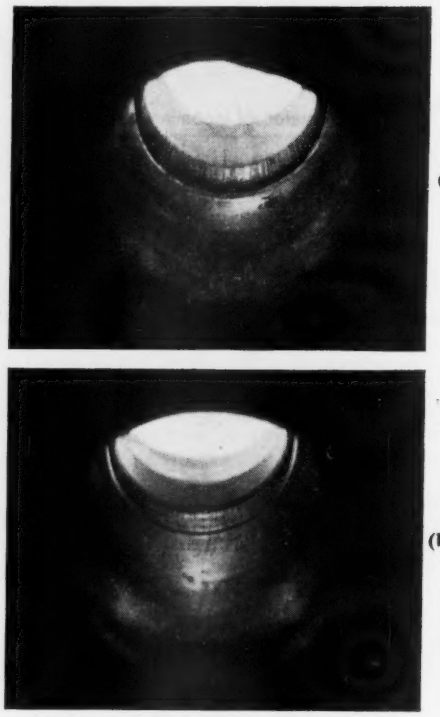
Light wear takes place well ahead of the working portion of the die profile, irrespective of back pull. Yet in these experiments the wire did not vibrate, and in the back-pull test it was constrained axially by heavy tension. Therefore, no contact between wire and die could have occurred ahead of the ring, so that this wear must have been caused by the lubricant. The copper wire was originally bright-annealed and smooth, and was lubricated by a solution of soap in water. The steel wire, on the other hand, was limed after annealing and pickling, in accordance with usual practice, and the lubricant in the experiments was powdered soap. Therefore, it would be expected that more abrasive matter would be found in the pocket between wire and die in the experiments with steel wire. In fact, dies *C* and *D* appear to have worn ahead of the ring more than dies *A* and *B*.

In all instances except that of die *B*, the position of the point of contact between wire and die relative to the ring favours the second hypothesis concerning the cause of ringing. Measurements were carefully checked, but no error has been detected. Of six other dies used in similar experiments, two showed this 'anomalous' behaviour. It is possible that a small lateral shift of the wire guides occurred during these three tests.

No firm conclusion can be made concerning the connection between back pull, the material of the wire, and the intensity of wear in the zone beyond the ring, because in spite of precautions the dies varied in hardness. The figures quoted on p. 163 are averages of eight indentations made on the top and bottom faces of the die pellets; these varied by as much as 20 points of V.P.N.

CONCLUSIONS

These experiments indicate that ringing is caused by the steep stress gradient near the point of entry of the wire, rather than by the abrasive action of a contaminated lubricant. It seems that the stress concentration causes local destruction of the die surface,



(a)

(b)

Fig. 3—Surfaces of worn dies, showing ringing: (*a*) Without back pull; (*b*) with back pull

and that the wire strikes the die wall at an ever-increasing angle, until a deep ring is formed with a leading face that often is inclined at more than 20° to the wire axis. At this stage the destruction of the die surface is greatly accelerated, and fairly large particles, torn out of the leading face of the ring, plough through the die, causing longitudinal grooving of the working surface (*see* Fig. 3*a*) and therefore poor wire finish.

Since the die stresses are indispensable to the process of deformation, ringing cannot be eliminated. The experiments demonstrate, however, that it is possible to reduce ringing considerably by means of back pull, and thus to preserve the smooth working surface of the di. (*cf.* Figs. 3*a* and *b*).

Acknowledgment

The author wishes to acknowledge the assistance of his colleague, Mr. J. Wilkes, who exercised great care in carrying out the drawing operations and the measurements of die profiles.

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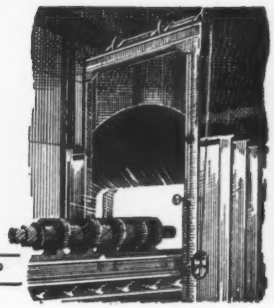

Hot Bloom and Slab Shears

By J. A. Kilby

SYNOPSIS

This paper is limited to a consideration of shears for the hot cutting of blooms and slabs more than 6 in. square and 18 in. wide × 2 in. thick, respectively. The subject is dealt with in broad outline only, and the main features of this type of equipment are reviewed.

Introduction

THE cutting of blooms and slabs is normally effected at ingot heat after cogging, and is necessary for sub-division into lengths suitable for further processing, and/or for the removal of the defective or discard material at the ends of the piece. Although it is an intermediate operation, accurate and clean cutting is essential, as failure to satisfy requirements in these respects may result in loss of yield or may give rise to difficulties during subsequent stages of manufacture.

Accuracy is particularly important for slabs which must be of definite sizes and weights to suit the plates for which they are intended. When the slab is over-sized the plate rolled from it will be larger than required, and the scrap loss will be excessive. If, on the other hand, the slab is under-sized, the plate will be too small to meet the specification and may have to be cut up for other orders, with consequent increase in the amount of scrap.

Whilst, in slab production, clean cutting and freedom from distortion are desirable properties, they are even more necessary in blooms which are subjected to additional mechanical working, especially rolling. 'Shear drag,' as the distortion at the end of the cut piece is called, is mainly caused by incorrectly set and/or worn blades, although excessively large clearances between the faces of the moving parts of the shear may also be contributory factors. When the drag is considerable, trouble may be experienced in entering the end of the bloom into the guides of succeeding mills; or, if reheating in continuous-pusher-type furnaces is necessary, difficulties in furnace operation may arise. The blooms may not pack neatly on the charging bench, and would then tend to get out of line during their passage down the furnace, with the possibility of causing damage to the side walls. In addition, rapid deterioration of the hearth may be caused by the sharp fin, which is left on the end of the bloom, acting as a ploughshare as the piece moves forward. The importance of providing equipment capable of satisfying the conditions for accurate and clean cutting is therefore obvious, and plant now available fulfils these requirements to a high degree.

Three processes have been introduced for the hot cutting of blooms and slabs, *i.e.*, sawing, gas-cutting, and shearing, but of these, only the last-named is of any significance at the present time. A great deal of attention is being directed to the development of gas-cutting equipment, but the relatively low operating speeds available have, so far, precluded its use in high-production mills. Nevertheless, when an extremely

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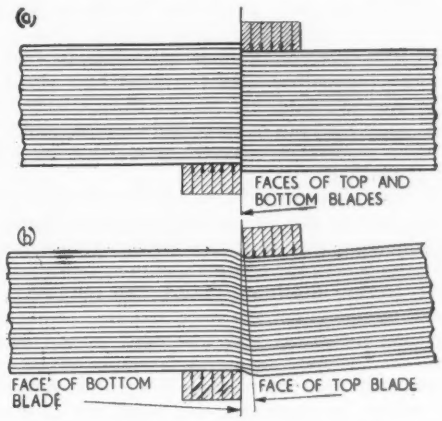


Fig. 1—Diagram showing (*a*) theoretical and (*b*) actual, shearing action

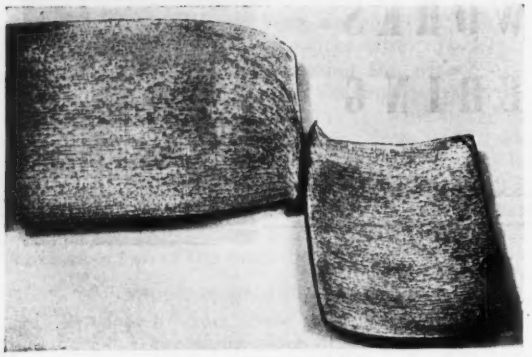


Fig. 2—Macro-etching taken from 8 in. × 8 in. bloom after cutting on a 14 in. × 14 in. hydraulic down- and up-cutting hot bloom shear

wide range of sizes has to be covered and the number of large pieces is relatively small, it may be more economical to provide a shear of moderate capacity for dealing with the bulk of the product, and to gas-cut the remainder.

SHEARING

The term 'shearing' is used to denote a system of cutting where severance is effected by subjecting the piece to shearing stress at the point where the cut is required. Shearing stress or shear is defined as the internal force acting along a plane between adjacent parts of a body when two equal forces, parallel to the plane considered, act on each part in opposite directions (*see* Fig. 1*a*). The attainment of this theoretical condition is not possible in practice, mainly because of blade wear and working clearances between the moving parts of the shear (Fig. 1*b*). From a study of this illustration and Fig. 2, which is a macro-etching taken from a bloom after cutting, it will be seen that the piece is subjected to a combination of stresses, and that the relative magnitudes and directions of these are influenced by the conditions during cutting.

Very little information has been published on shear stress values for steel at elevated temperatures, and experiments carried out at the Blochairn Works of The Steel Company of Scotland, Ltd., prior to the installation there of the first slab shear, in 1884, are therefore interesting. At the time this shear was under consideration, no data was available which would enable its power to be determined, and it was therefore necessary to establish a value by experimental methods.

The tests were carried out in a very simple manner, billets of a suitable size and at varying temperatures being inserted into fork-type adaptor pieces, which were attached to the loading members of an ordinary tensile testing machine. Load was applied in the normal manner, and the force required to shear the piece was measured and was used as the basis of design for the new shear. A facsimile of the report dealing with these experiments is reproduced in Fig. 4.

As might be expected, the resistance of steel to shear is a function of temperature, which is influenced by the cross-sectional area of the piece to be cut; in general, the larger piece will have a higher average temperature and a lower shear stress per unit of area. In the absence of precise values an attempt has been made to assess their magnitude, and the blade loads of a number of shears of British, American, and Continental makers, have been analysed with reference to the maximum cross-sectional area to be cut; the results of this investigation are shown graphically in Fig. 3. It is appreciated that shear designers have worked empirically in fixing blade loads, but, as with many other items of rolling-mill equipment, the variables are so considerable that when all allowances have been made for these it is extremely doubtful whether a more academic approach to the problem would give better results.

SHEARS

A shear, or guillotine as it is perhaps more aptly called in some works, consists essentially of two blades arranged parallel to one another, with their faces in approximately the same vertical plane and normal to the horizontal axis of the piece to be cut. The distance between the edges of the blades in their extreme open position is sufficient to allow the maximum section rolled to pass through freely. Means are provided for moving either or both blades relative to one another so that in the closed position they overlap slightly, thus ensuring complete severance of the piece.

Shears differ in three fundamental respects, *i.e.*, direction of cutting, method of developing cutting power, and construction of the frame; the variants of these may be combined in any way desired.

The cut is made by moving the blade(s) in a horizontal or vertical direction; the systems in use are shown diagrammatically in Figs. 5*a–d*. Most of the shears now being built are of the types illustrated in Figs. 5*c* and *d*.

The power required to effect the cut may be applied to the blades either hydraulically or mechanically, and at the present time all except the very largest units use the mechanical system. The cutting power can be developed in a number of ways to suit each of the two systems.

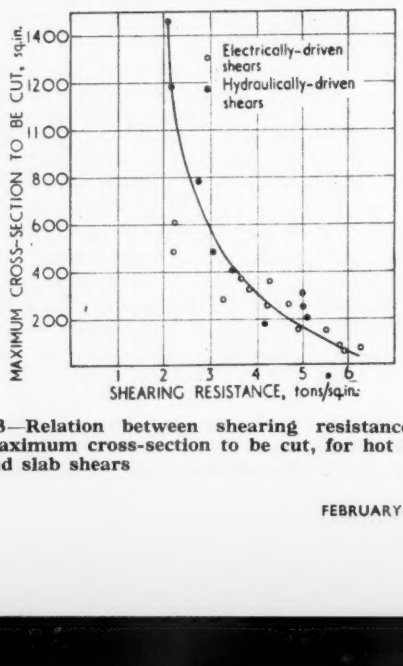
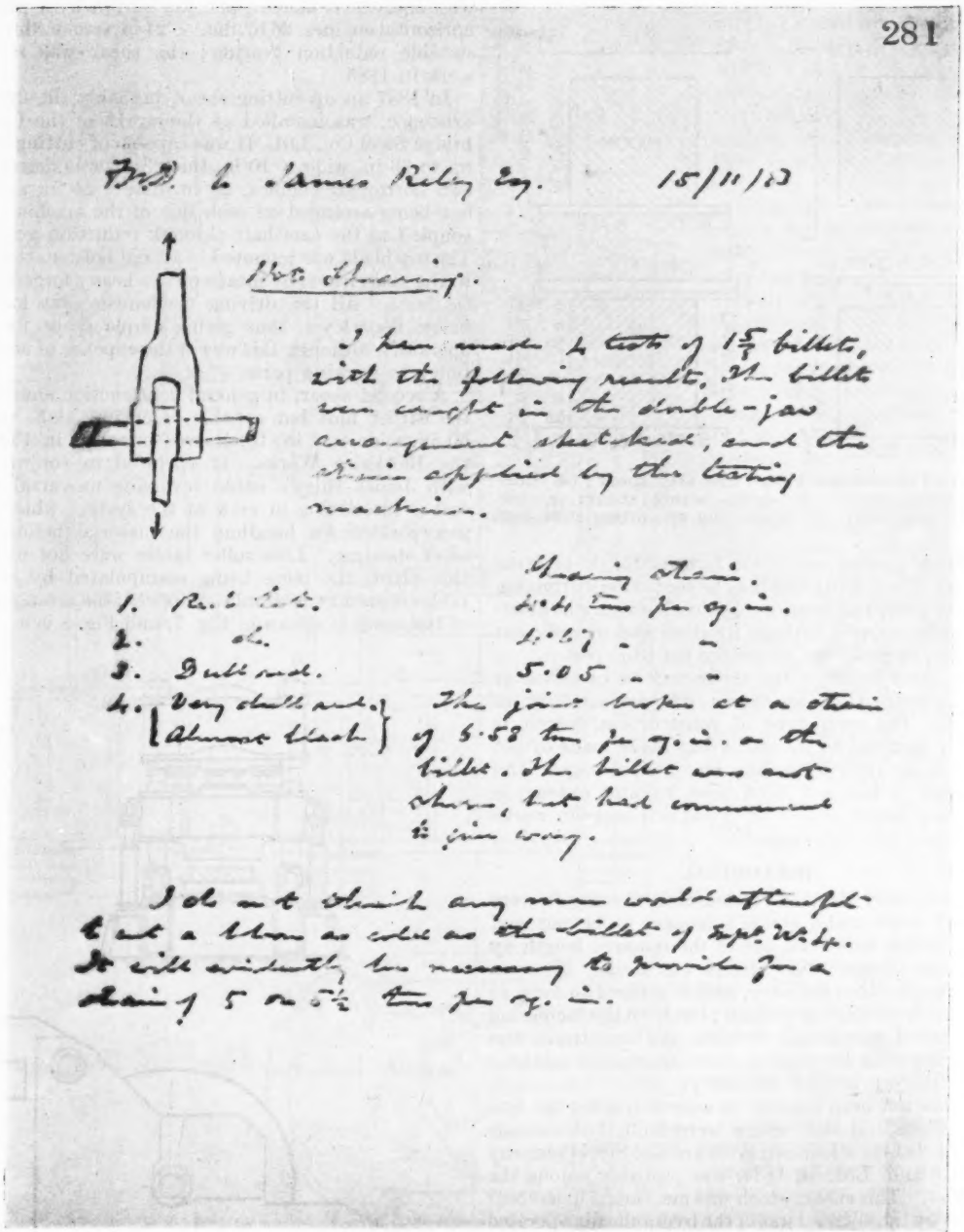


Fig. 3—Relation between shearing resistance and maximum cross-section to be cut, for hot bloom and slab shears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Bro. to James Kilby Esq. 15/11/13
Hot Shearing.
I have made 4 tests of 1 5/8 billets, with the following results. The billet was caught in the double-jaw arrangement sketched, and the strain applied by the testing machine.
Shearing strain.
1. Red hot. 4·84 tons per sq. in.
2. do. 4·67 " "
3. Dull red. 5·05 " "
4. Very dull red. Almost black } The joint broken at a strain of 5·58 tons per sq. in. on the billet. The billet was not sheared, but had commenced to give way.
I do not think any man would attempt to cut a bloom as cold as the billet of Sept. 11th. It will evidently be necessary to provide for a shear of 5 or 5½ tons per sq. in.

Fig. 4—Facsimile of report on hot shearing tests carried out at the Blochairn Works of The Steel Company of Scotland, Ltd.

In shears using the hydraulic system, force is exerted on the blades by means of direct-acting cylinder(s) which are supplied with water at medium or high pressure as required to satisfy the cutting duty. Hydraulic power at the required pressure is generated in two ways :

(i) By intensifier units using compressed air, steam, low-pressure water, or electricity, as the source of primary power.

(ii) By steam or electrically driven reciprocating or rotary pumps, feeding direct to the shear or working in conjunction with weight- or air-loaded accumulators.

As mentioned previously, hydraulic operation is now favoured only for the largest-capacity units, which usually employ method (ii).

When the cutting power is to be developed mechanically, shear is driven by a prime mover through

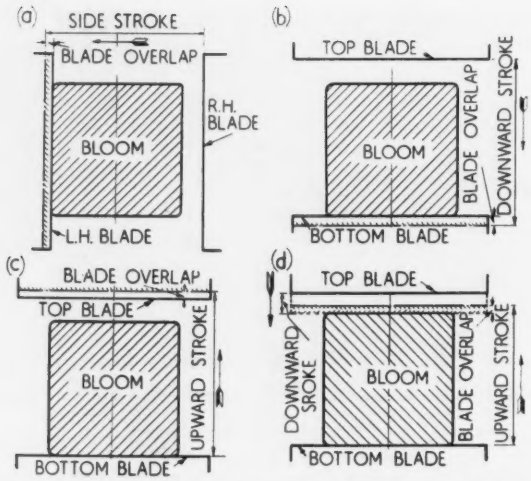


Fig. 5—Types of hot bloom and slab shear : (*a*) Side-cutting shear; (*b*) down-cutting shear; (*c*) up-cutting shear; (*d*) down- and up-cutting shear

reduction gearing and some form of toggle or lever system. The driving unit may be continuously running with flywheel and disengaging clutch, or may be intermittently running without flywheel and of sufficient capacity to make the maximum cut from rest.

The main frame of the shear may be of closed or open construction, as shown diagrammatically in Fig. 6. The open type of construction, which is usually confined to shears having blade loads of not more than 1500 tons, has many advantages, and although it has not been used to any extent in America, is now almost universal in European works for shears up to this capacity.

HISTORICAL

In the early days of steelmaking, the ingots were cogged down under steam hammers to blooms and slabs, which were then cut to the required length by the same means. This system was already in use in the wrought-iron industry, and it sufficed so long as outputs were relatively small ; but with the increasing capacity of open-hearth furnaces, and the introduction of rolling mills for cogging duty, alternative methods of cutting-up became necessary.

It has not been possible to ascertain when the first hot bloom and slab shears were built, but the one installed at the Blochairn Works of The Steel Company of Scotland, Ltd., in 1884, was probably among the earliest. This shear, which was mentioned in a recent paper by the author,[1] was of the hydraulically operated down-cutting type, having a single 36-in. dia. cylinder and designed to cut slabs up to 24 in. wide × 8 in. thick ; hydraulic power at a pressure of 1 ton/sq. in. was supplied by a pair of steam pumping engines.

At about the same time as the developments at the Blochairn Works were taking place, the new rolling plant at the Glengarnock Works of Merry and Cunninghame, Ltd., was under construction, and a shear of quite different design was being installed. This was also of the down-cutting type, capable of dealing with slabs up to 30 in. wide × 9 in. thick, and with equivalent blooms, and was driven by a pair of horizontal engines, 26 in. dia. × 24 in. stroke, through suitable reduction gearing ; the shear was set to work in 1885.

In 1887 an up-cutting shear, probably the first in existence, was installed at the works of the Clydebridge Steel Co., Ltd. It was capable of cutting slabs up to 36 in. wide × 10 in. thick, and was driven by two horizontal engines, 26 in. dia. × 24 in. stroke, one being arranged on each side of the machine and coupled to the camshaft through reduction gearing. The top blade was mounted in a fixed bolster attached to the main frame by means of two heavy forged-steel tie bolts. All the driving mechanism was located below floor level, thus giving ample space for the operators, although this was at the expense of accessibility to working parts.

A second shear, in general construction similar to the earlier unit but capable of cutting slabs up to 60 in. wide × 8 in. thick, was installed in 1890 at the Blochairn Works. It operated in conjunction with James Riley's noted reversing universal mill, and is interesting in view of the system which was incorporated for handling the material before and after shearing. Live roller tables were not used in this plant, the piece being manipulated by sliding tables moved by hydraulic cylinders ; the arrangement of the shear is shown in Fig. 7, and Fig. 8 is a works

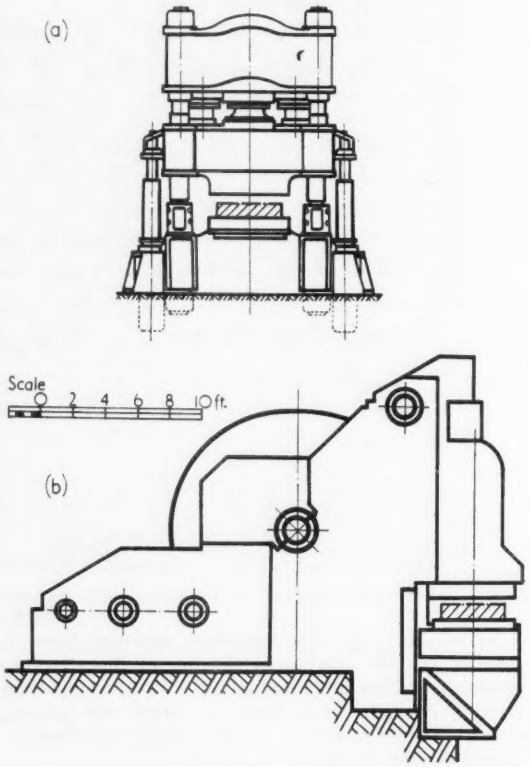


Fig. 6—Construction of hot bloom and slab shears: (*a*) Closed-frame construction; (*b*) open-frame construction

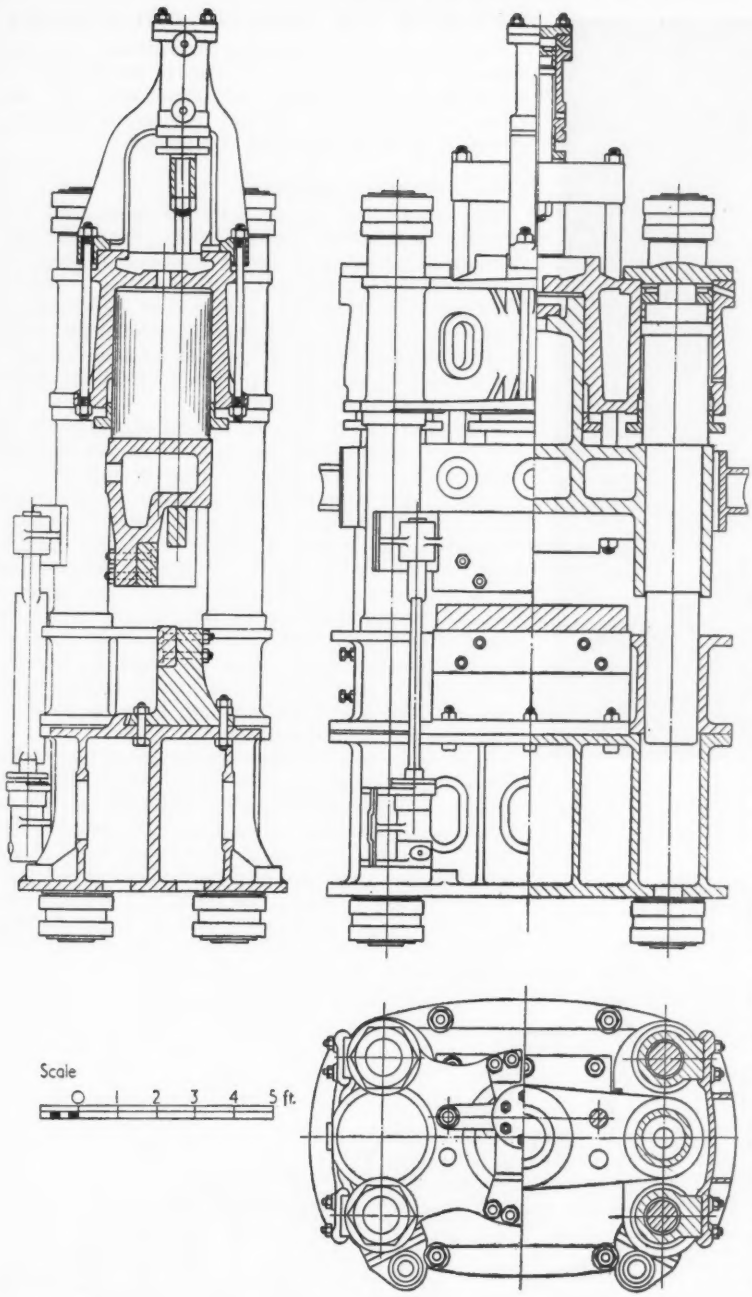


Fig. 7—Arrangement of 60 in. × 8 in. hydraulic down-cutting hot slab shear

view taken shortly before the machine ceased operation in 1944.

Although the hydraulic shear was quite successful, most of the shears built before 1900 were of the steam-engine-driven down-cutting type, of the same general construction as the Glengarnock unit. Some extremely large machines were built, including one installed at the Dalzell Works of D. Colville and Sons, Ltd. (now Colvilles, Ltd.) in 1894, which was able to deal with slabs up to 60 in. wide × 12 in. thick (*see* Fig. 9). The driving engines of all shears of this type were powerful enough to effect the cut from rest, thus avoiding the use of the flywheels and clutches associated with continuously running prime movers.

Early in the present century the intensifier unit for the generation of high-pressure water was applied successfully to large shears. Many plants were built, using steam, compressed air, and water, as the low-pressure medium, but the trend towards the use of electricity for main and ancillary machinery led to the development of the electrically driven shear. Among the earliest units of this type was the side-cutting shear shown in Fig. 10, which is capable of cutting blooms up to 10 in. × 10 in. The up-cutting and down- and up-cutting shears, both hydraulically and electrically operated, and the open-sided shear, were introduced during the period 1915–1925, which was one of intense activity in this branch of steelworks engineering. There have been no fundamental changes in shear design during recent years, efforts having been concentrated on the improvement of constructional details to ensure uninterrupted service under all conditions.

OPERATIONAL REQUIREMENTS

Operational requirements are relatively few, but often present considerable difficulty to the designer. As mentioned previously, the most important of these is the clean and accurate cutting of all sizes within the capacity of the shear, at a speed sufficiently high to avoid interference with mill operation even when dealing with short pieces. To ensure that the plant is sound economically, it must be laid out so that the capital cost is not excessive in relation to the tonnage throughput ; moreover, labour for operation and upkeep, and the consumption of power and other services, must be at a minimum.

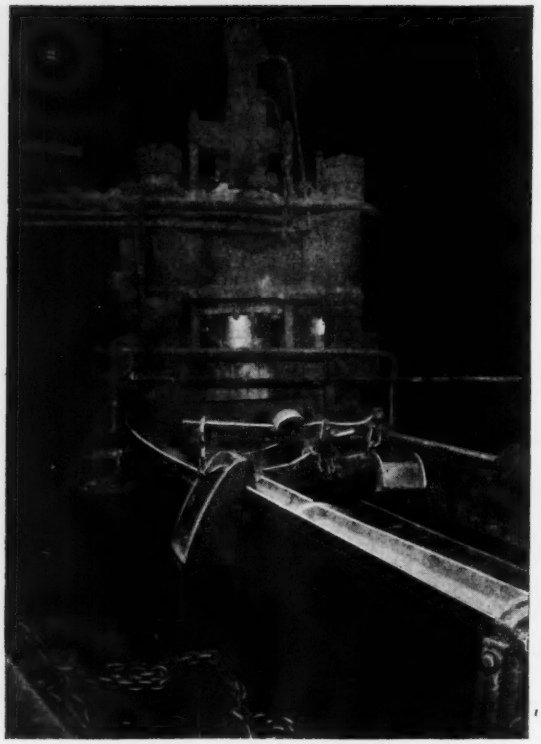


Fig. 8—View of 60 in. × 8 in. hydraulic down-cutting hot slab shear (built 1890) at Blochairn Works, shortly before shear ceased operations in 1944

EQUIPMENT FOR SHEARING INSTALLATIONS

Hot bloom and slab shearing installations comprise shear and drive equipment, equipment for feeding the rolled stock to the shear and evacuating the cut pieces, crop-end removal and handling equipment, and slab or bloom handling equipment.

Shear and Drive Equipment

The shear comprises not only the mechanism for effecting the actual cut, but also a clamping or holding-down device, located as close to the blade as possible, to prevent the piece moving during cutting. Where the shear is required for cutting short and medium lengths, a stop measuring gear is provided for exact positioning of the piece ; it can also be used for turning the short pieces or crop ends to facilitate their movement along the roller table.

When the type of shear for a particular application has been decided, the main proportions can be fixed fairly easily, and although the methods employed are empirical, they have been well proved over long years of experience and can therefore be safely accepted.

Blade Load—Figure 4 shows that the specific resistance of the steel to shear and its relationship to the maximum cross-sectional area of the piece to be cut follow a definite curve, from which values for any desired cutting duty can be assessed. Most of the shears on which this curve was based are cutting mild steel ; where alloy steels of smaller cross-section, and therefore lower temperature, have to be dealt with, the values obtained would be higher.

Shear Opening—The shear opening must be capable of passing the maximum section with ample allowance for split or badly formed ends. The usual practice is to make the distance between the two blades in the maximum open position equal to the depth of the largest section plus two or three inches. The length of the blades is usually the width of the maximum piece plus 2–6 in., and in closed-frame shears the clear opening is greater than this by an amount which is influenced by design considerations.

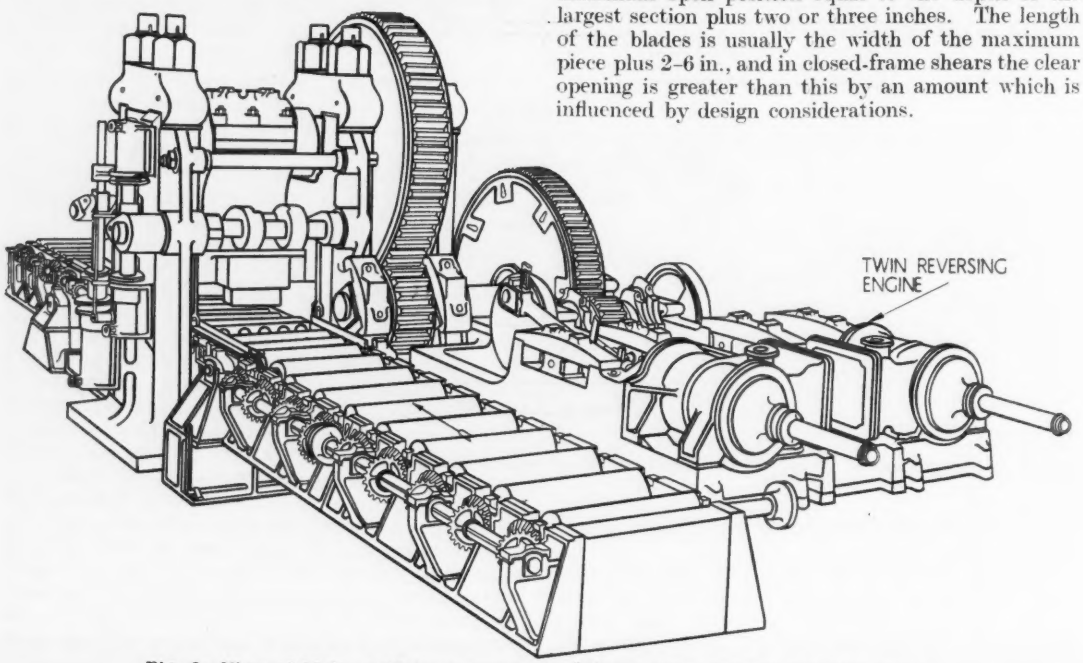


Fig. 9—View of 60 in. × 12 in. steam-engine-driven down-cutting hot slab shear

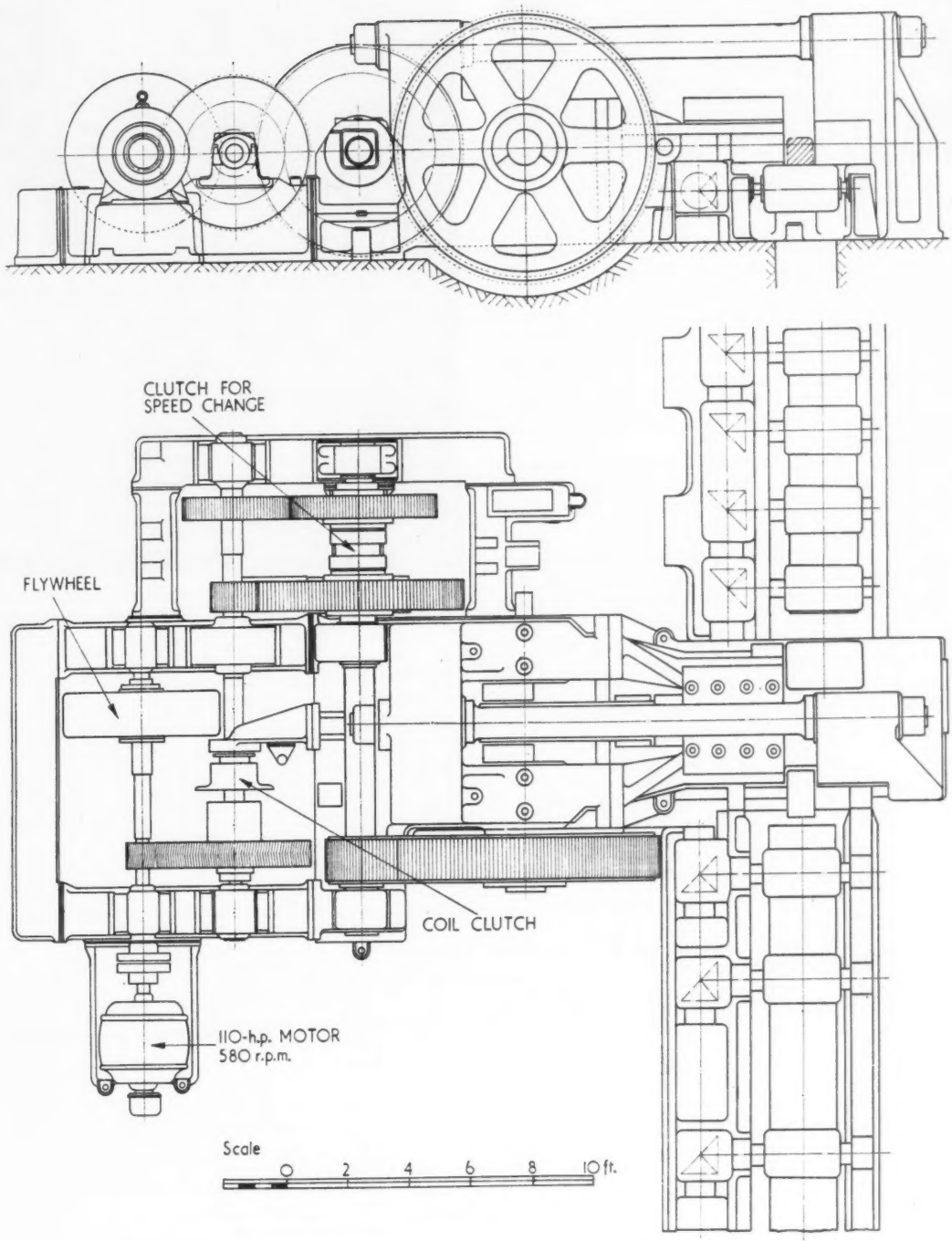


Fig. 10—Arrangement of 10 in. × 10 in. electrically driven side-cutting hot bloom shear

Fig. 11—Typical crop ends from a 66 in. × 18 in. steam-hydraulic down-cutting hot bloom and slab shear

Stroke of Shear—The total stroke of the shear is equal to the distance between the two blades plus ½–1 in. overlap.

Speed of Cutting—The speed of cutting depends on the cross-sectional area of the piece, and varies, in hydraulic shears, from 2 to 6 inches per second, and in mechanically driven shears from 3 to 15 strokes per minute. Where the shear is required to handle a wide range of sizes, the cutting speed is necessarily a compromise.

When these leading data have been established the shear can be designed by orthodox methods, but particular attention must be paid to constructional details, as follows :

(i) The blades must be easily accessible for servicing, and should be symmetrical so that they can be turned to enable maximum use to be made of the cutting edges. A substantially proportioned steeling should be provided between the blade and the apron or bolster, to minimize wear of these parts and to facilitate re-alignment of the blade.

(ii) The apron or bolster, where movable, must be effectively guided, and must be designed to accommodate a lateral force equal to one half of the blade load.

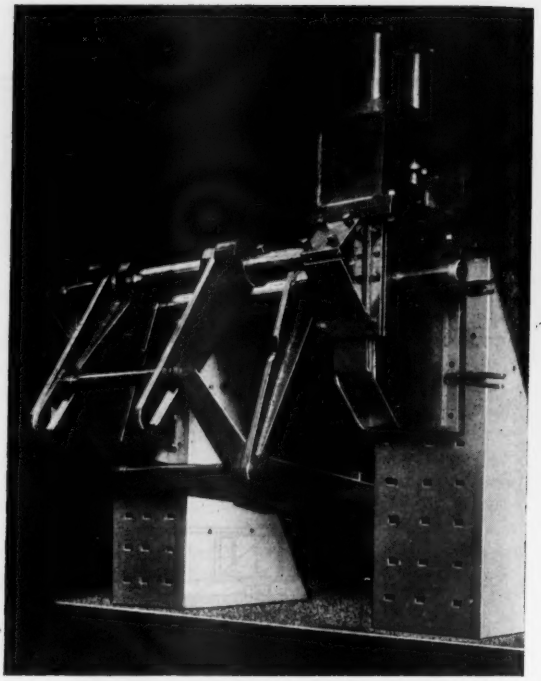


Fig. 12—Erection view of crop-end pusher for 40 in. × 10 in. steam-hydraulic down- and up-cutting hot bloom and slab shear

(iii) All moving parts should be balanced.

(iv) Clearances between working parts should be liberal, and the general construction of the shear should be such that it will operate satisfactorily even under conditions of considerable temperature difference.

(v) Allowance must be made for eccentric loading of the shear resulting from incorrect entry of the piece.

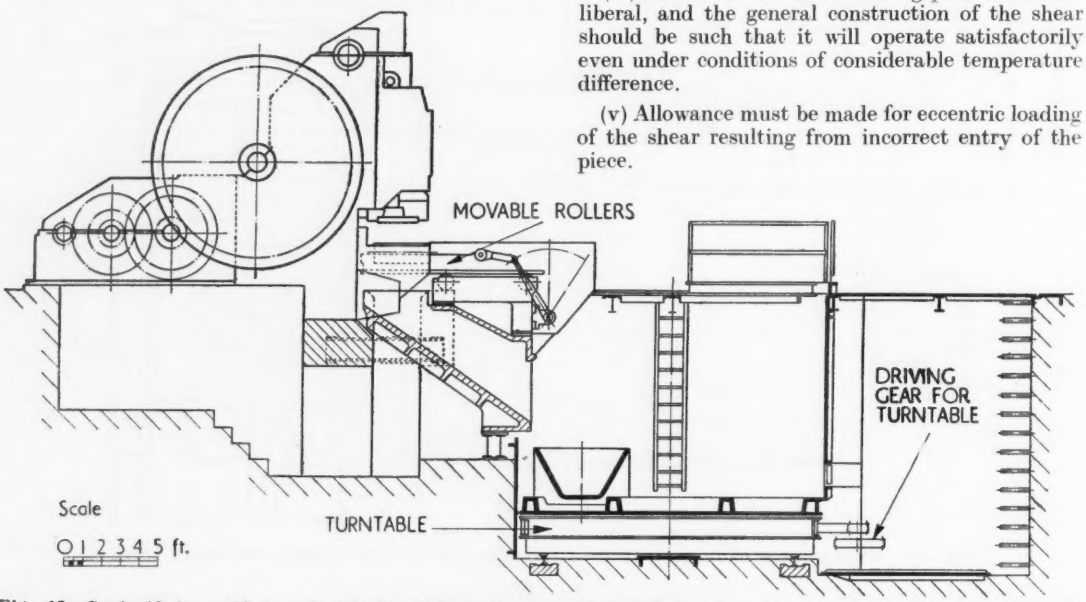


Fig. 13—Sack 12 in. × 12 in. electrically driven down- and up-cutting hot bloom shear. Cross-section of crop-end handling equipment

Fig. 14—Sack 12 in. × 12 in. electrically driven down- and up-cutting hot bloom shear. View of crop-end skips on turntable

(vi) The parts of the shear lying below floor level should be constructed so that the scale can fall away freely.

Equipment for Feeding Rolled Stock to Shear

The rolled bloom or slab is usually conveyed from the mill to the shear by means of live rollers, those immediately adjacent to the shear being at somewhat closer centres than the others, and often of collared or interlocking construction. Fixed or adjustable guides, the latter being hand or power operated, are occasionally fitted to ensure the piece entering the shear on the centre of the blade, thus avoiding eccentric loading. After cutting, the pieces are conveyed from the shear by live rollers, frequently of collared construction, for distribution as required.

In down-cutting shears, the section of rollers lying below the top apron is arranged as a depressing table, its length being sufficient to give a relatively flat angle when in its lowest position.

The following details require close attention during design of the tables :

(i) The distance from the shear blade to the rollers immediately adjacent thereto should be as small as possible, to ensure the movement of short pieces.

(ii) The pitch of the rollers in the tables should not be more than 60% of the length of the shortest piece to be handled.

(iii) The top of the rollers should be slightly higher than the cutting edge of the bottom blade, so that the danger of the end of the piece damaging the blade is reduced to a minimum.

(iv) The construction of the tables and the clearances between the working parts should be such that considerable variations in temperature will not affect their operation. In the event of an interruption of operations beyond the shear, heavy bloom or slab sections at high temperature may remain on the tables for long periods. This results in heating of the rollers and other machinery parts, with consequent expansion of these, and the danger of seizing-up.

(v) Where depressing tables are used, a heavy apron plate or beam should be rigidly attached to

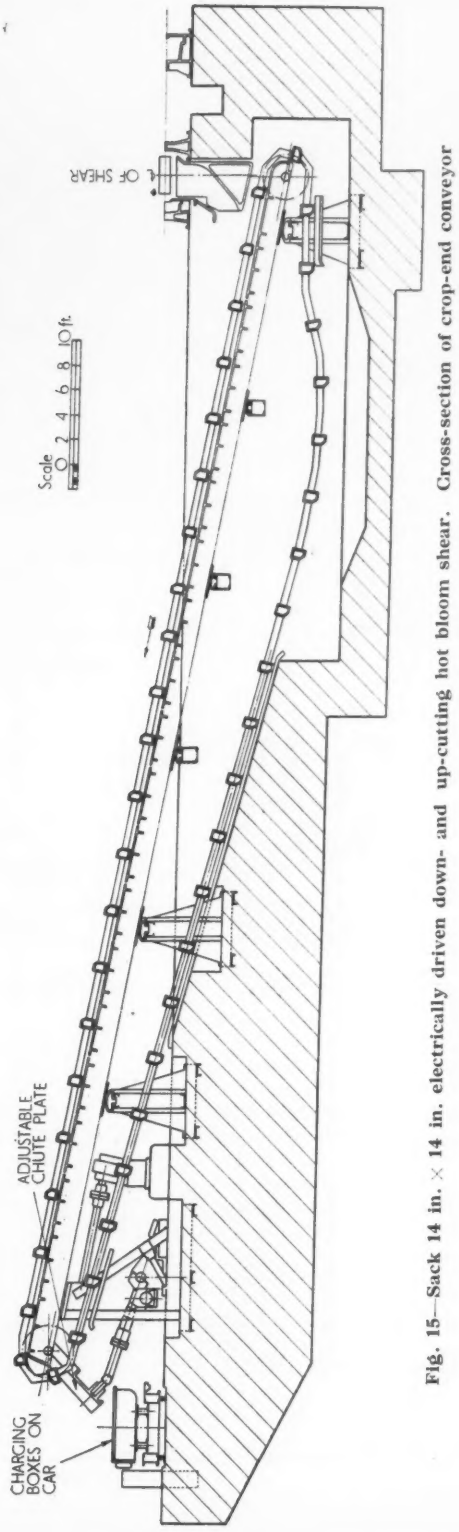


Fig. 15—Sack 14 in. × 14 in. electrically driven down- and up-cutting hot bloom shear. Cross-section of crop-end conveyor

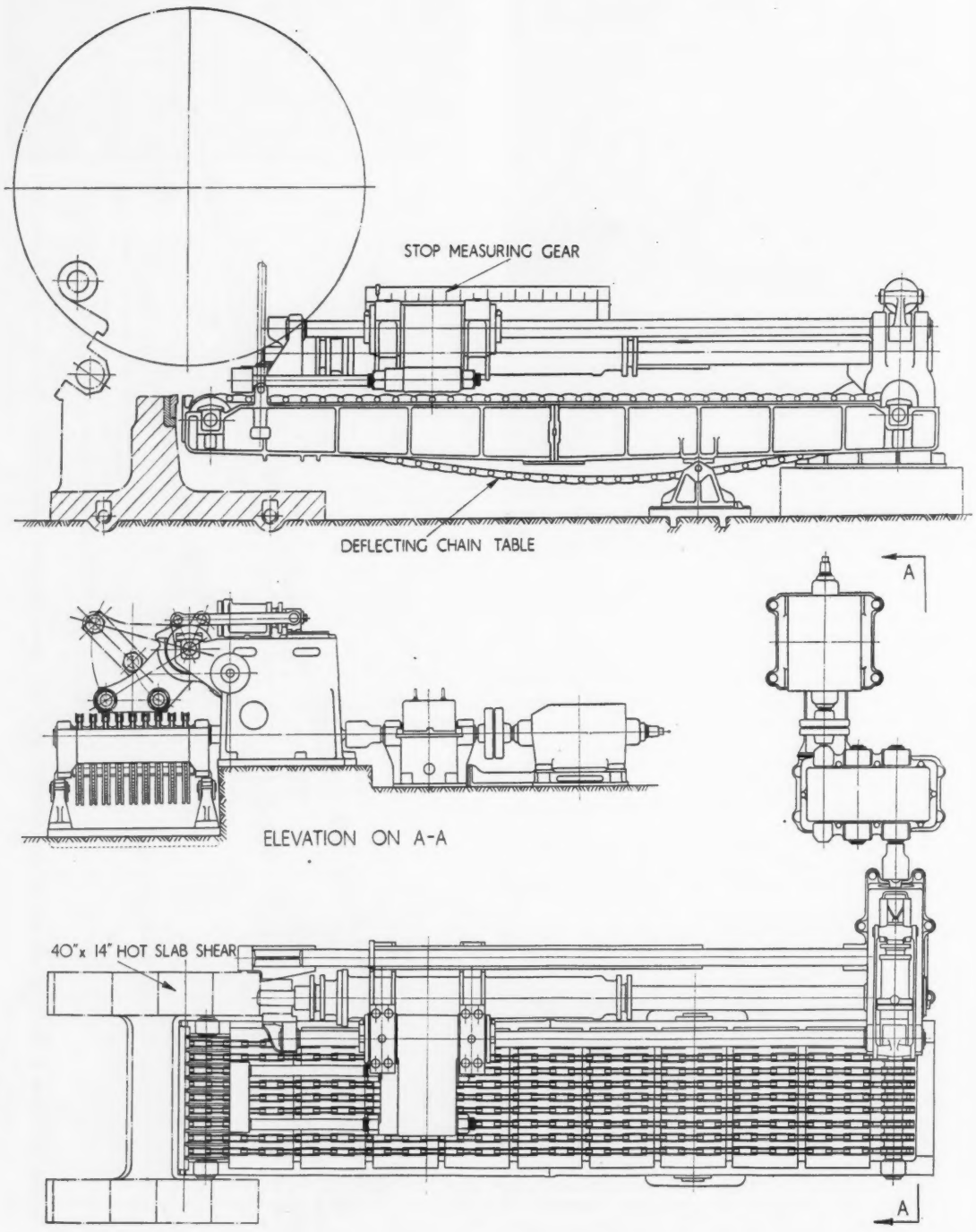


Fig. 16—Arrangement of depressing-chain table and stop measuring gear for 40 in. × 14 in. steam-engine-driven down-cutting hot slab shear (Scale: 1 in. = 4 ft.)

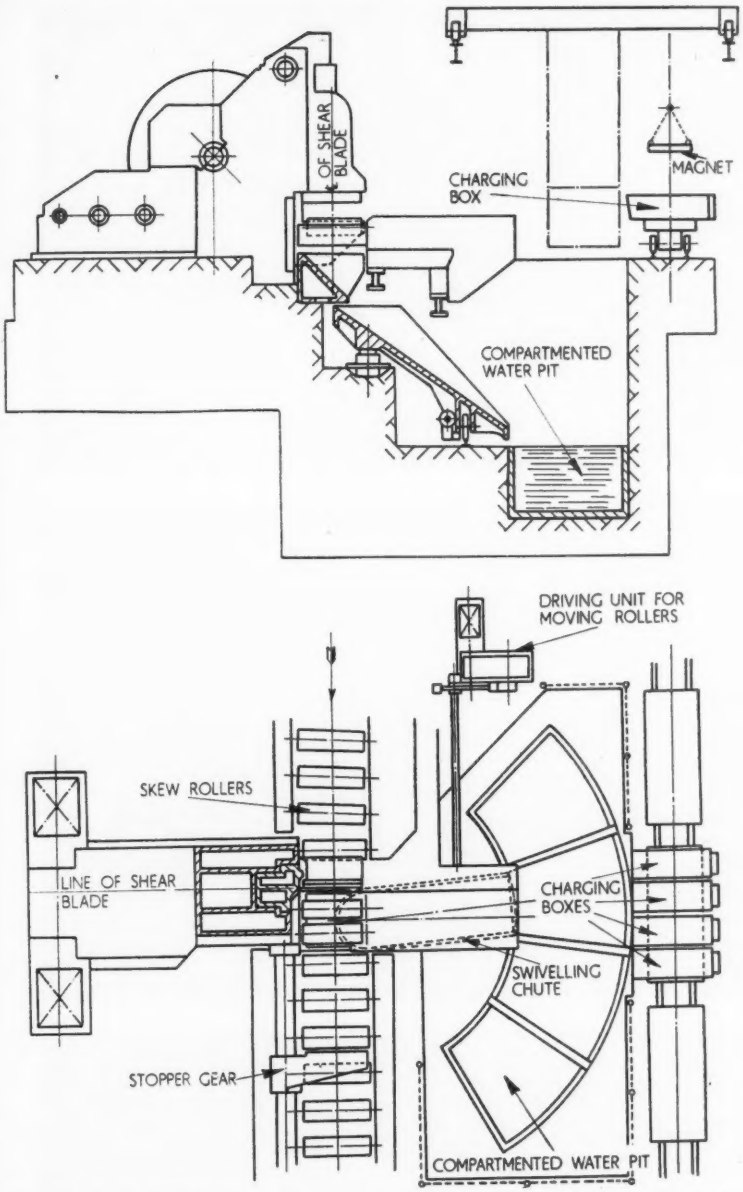


Fig. 17—Sack electrically driven down- and up-cutting hot bloom and slab shear. Layout of crop-end disposal equipment (Scale: 1 in. = 11 ft.)

the main frames of the table at the end adjacent to the bottom blade ; this transmits the push from the top blade through the piece on to the table structure.

Crop-End Removal and Handling Equipment

The handling of crop ends is a major problem in most plants. This is due not only to the relatively large number of pieces, but also to their size and shape. Figure 11 shows some typical crop ends from a 66 in. × 18 in. steam-hydraulic down-cutting hot bloom and slab shear. Another complication in plants producing alloy steels is the necessity for segregating the scrap according to its analysis, and considerable trouble and expense can be incurred in carrying out this procedure.

The amount of scrap arising at the shear depends on the type of steel, and may vary from 10 to 20%, this being taken from the top and bottom of the ingot in the approximate ratio of 2 : 1.

In the earliest installations the crop ends were removed from the shear delivery table by means of hydraulic or steam operated jib cranes, which deposited the pieces on to the floor or into wagons for returning to the melting shop. The same cranes were also used for handling the blooms and slabs, and no undue difficulties were experienced in working the system, as the outputs at that time were relatively small. With increasing demands, however, alternative methods of dealing with the scrap were developed, and many mechanical devices have been introduced to minimize labour and expense at this stage.

The type of equipment used is influenced by the frame construction of the shear. If this is of closed construction, the piece must first be pushed through the shear; this is effected, most simply, by the bloom pushing the front crop forward, the back crop being left on the bolster until the next bloom carries it through. This method is not always desirable, and mechanical push-through devices are now usually fitted to closed-frame shears. An erection view of a typical hydraulically operated parallel motion crop-end pusher, as fitted to a 40 in. × 10 in. steam-hydraulic down- and up-cutting hot bloom and slab shear, is shown in Fig. 12.

The crop ends may then be pushed sideways from the shear delivery table into skips or charging boxes arranged alongside; alternatively, a gap may be created in the table (by means of a swinging roller or a retractable section of the table) wide enough for the piece to fall through on to an inclined chute and thence into skips. These may be mounted on a turntable accommodating three or four skips, so that as soon

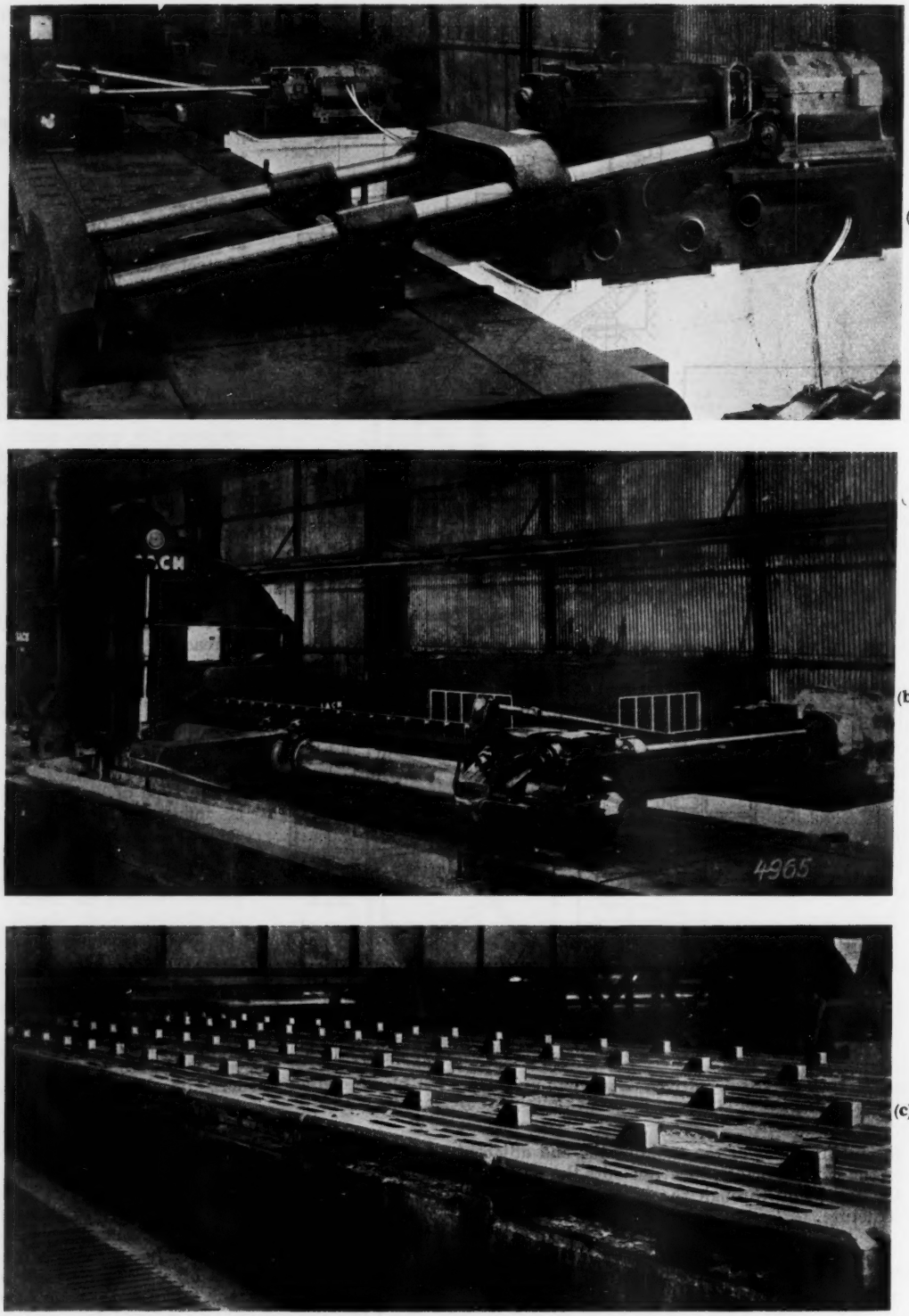


Fig. 18—Sack 12 in. × 12 in. electrically driven down- and up-cutting hot bloom shear : (*a*) Works view of bloom pusher ; (*b*) works view of shear, showing stop measuring gear ; (*c*) works view of reciprocating bar-type skid bank

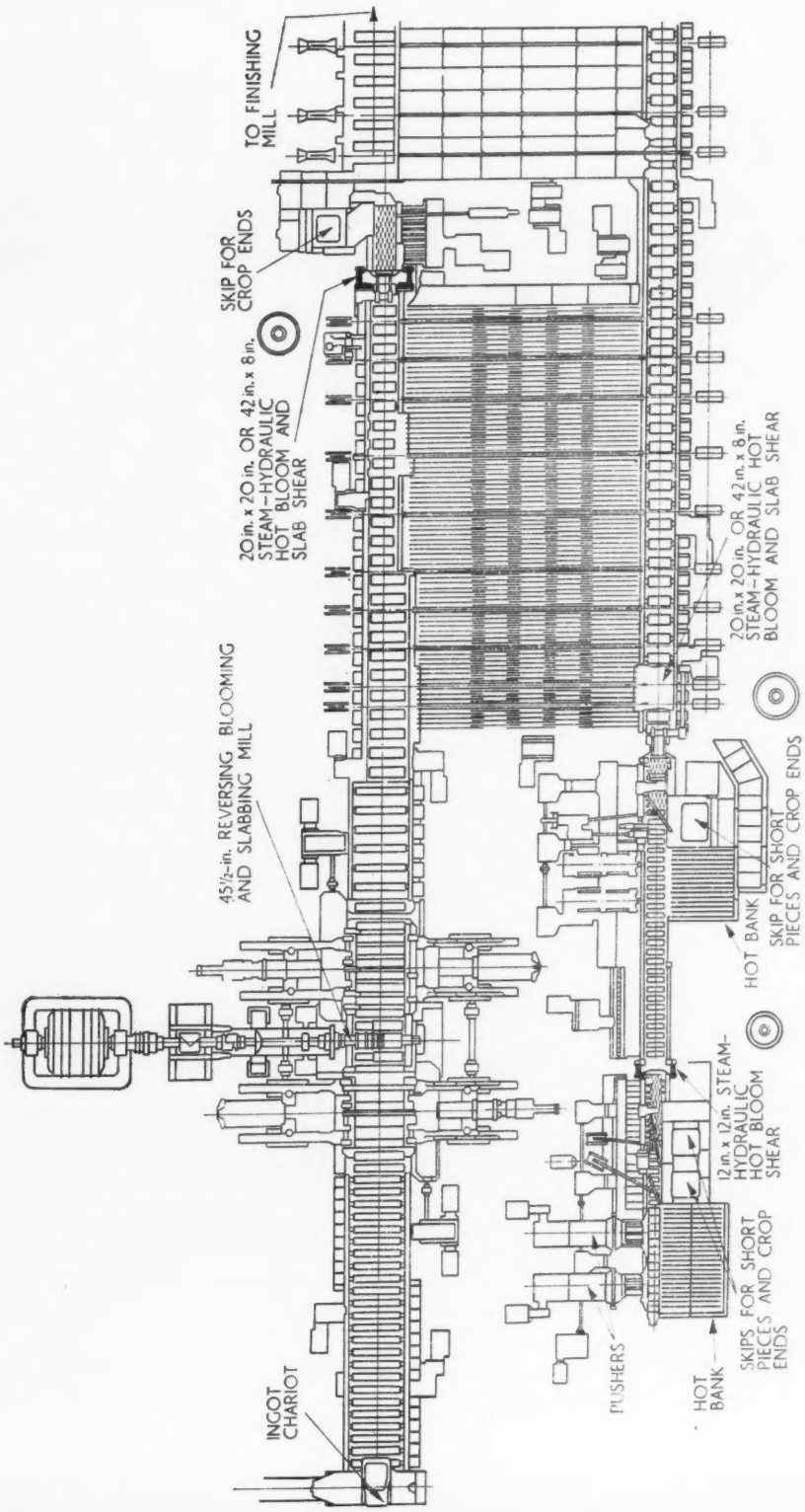

TO FINISHING MILL
SKIP FOR CROP ENDS
20in. x 20 in. OR 42 in. x 8 in. STEAM-HYDRAULIC HOT BLOOM AND SLAB SHEAR
20in. x 20 in. OR 42 in. x 8 in. STEAM-HYDRAULIC HOT BLOOM AND SLAB SHEAR
45½-in. REVERSING BLOOMING AND SLABBING MILL
HOT BANK
SKIP FOR SHORT PIECES AND CROP ENDS
12 in. x 12 in. STEAM-HYDRAULIC HOT BLOOM SHEAR
SKIPS FOR SHORT PIECES AND CROP ENDS
PUSHERS
HOT BANK
INGOT CHARIOT

Fig. 19—Layout of 45½ in. reversing blooming and slabbing mill plant, showing bloom and slab shears

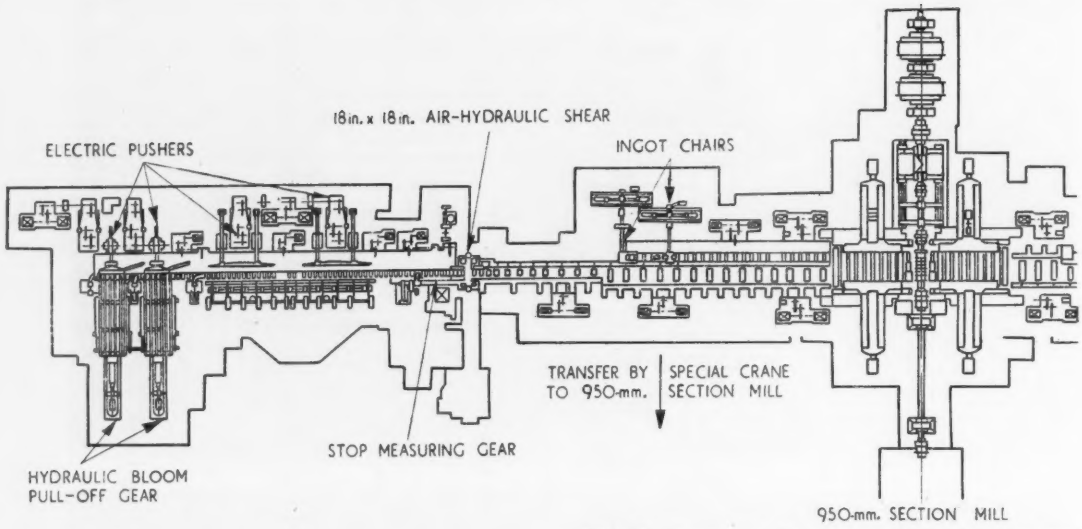


Fig. 20—Layout of 45½ in. reversing blooming and

as one is filled another can be brought into position ; this arrangement also has the advantage that scrap of different qualities can be separated. Figure 13 illustrates an installation of this type, and Fig. 14 shows the partially filled skips. Alternatively, the scrap may be delivered over the chute on to a heavy drag-bar-type conveyor, which carries it to a convenient point for direct loading into wagons (*see* Fig. 15).

With the open-frame shear it is possible to remove crop ends directly after cutting, by means of two pushers mounted one on each side of the blades. These discharge the crop ends sideways from the table, over an inclined plate into one or more skips arranged alongside.

The difficulty of conveying crop ends and short slabs by roller table, even when equipped with close-pitched interlocking rollers, led to the use of the chain table ; Fig. 16 shows a typical installation. Although quite effective in operation, chain tables were seldom used, because of heavy maintenance charges.

Other systems have been developed, in an attempt to simplify and cheapen the handling of what is, in effect, a waste product. As an example, Fig. 17 illustrates the crop-end disposal equipment applied to two large shears under construction at the present time. The scrap is discharged into a compartmented water pit, from which it is removed, after cooling, by magnet crane, and is placed in charging boxes on cars for return to the melting shop.

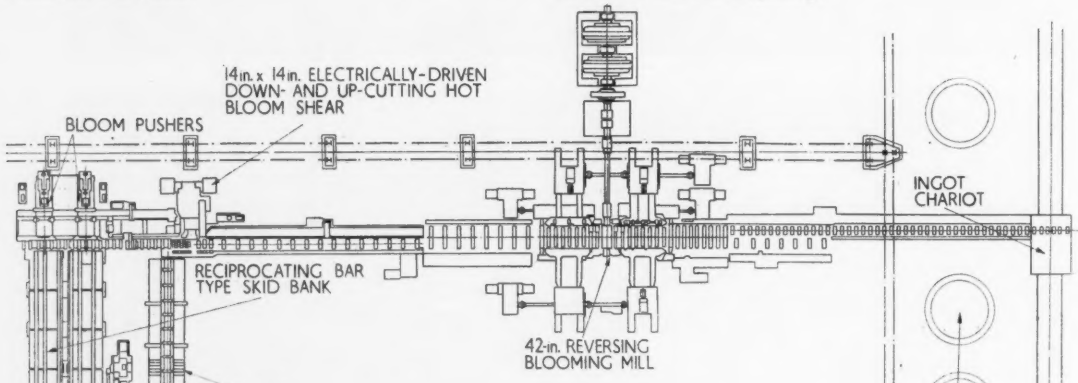
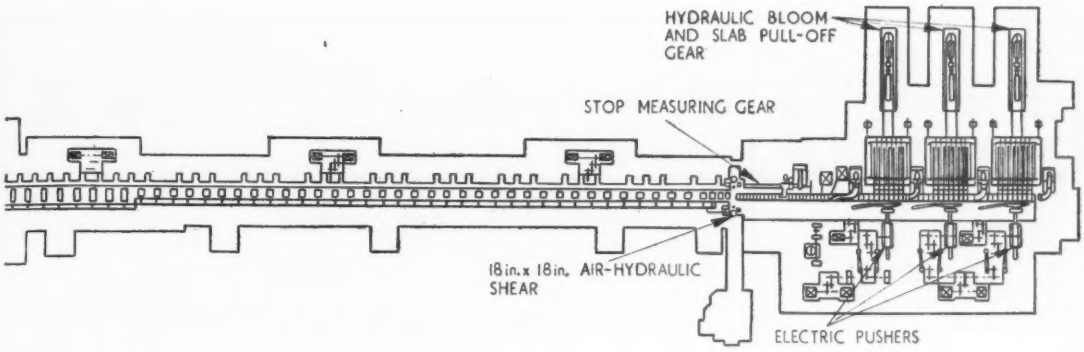


Fig. 21—Layout of 42 in. reversing blooming mill plant showing shearing equipment



slabbing mill plant with two shears

Slab or Bloom Handling Equipment

After shearing, the blooms and slabs must be disposed of as quickly as possible to avoid interference with mill operation. The cut pieces were, originally, removed from the shear delivery table by jib cranes, which placed them in wagons for transference to the finishing mills. This system, with overhead cranes, is still used occasionally, especially for large pieces, but it is not suited to high-capacity units producing blooms and slabs of light and medium section, and these are now dealt with almost entirely by the use of floor-mounted mechanical equipment.

The material may be handled in various ways :

(i) The piece may pass straight forward to other mills, with or without reheating.

(ii) The piece may be transferred sideways, by skid gear or charging machine, for delivery to other mills, without reheating.

(iii) The piece may be transferred sideways by pushers, skid gear, or a combination of these, on to a bank for cooling.

(iv) When relatively short-length pieces are being produced, these may be collected in skips arranged alongside the shear delivery table, adjustable switchplates being provided for diverting the piece into these skips.

The necessary machinery for fulfilling the above functions is subjected not only to heavy mechanical loading, but also to considerable increases in temperature, and provision must be made for these conditions in the design of the equipment. The main items of plant are as follows :

Roller Tables—Where the blooms or slabs are to be moved sideways from the roller tables, these are frequently of the overhung type. With this design all bearings and driving gears are located on the remote side, where they are not subjected to direct heat from the material.

Skid Gears—These may be of the normal rope type, but usually chain or reciprocating bar skids are used, these being more suited to the arduous operating conditions.

Pushers—Pushers for moving the piece sideways across the roller table may be hydraulically or electrically operated. With either system it is essential that the design precludes the possibility of damaging the pusher in the event of failure to retract the head before the next piece advances along the roller table. This end can be achieved by the use of articulated pusher fingers attached to the head, or by giving the head a horizontal forward motion and a lifting return motion.

Cooling Banks and Piling Devices—The main requirements for these units are robust, all-steel construction, freedom for expansion, and carefully designed foundations. Large masses of hot steel are constantly in contact with this machinery, and unless the heat can be readily dissipated, rapid deterioration will set in.

A typical well-planned shearing installation is shown in Fig. 18, which shows views of a 12 in. × 12 in. electrically driven down- and up-cutting bloom shear, as seen from the delivery side.[2]

LAYOUT OF SHEARING EQUIPMENT

The layout of the shearing plant is influenced mainly by the type of product and by the further processing units which have to be served with blooms or slabs.

Usually, the shear is located on the side of the mill remote from the soaking pits, although occasionally it may be installed on the same side. Where plant layout conditions justify such an arrangement, two shears may be provided, one on each side of the mill ; generally, however, a single shear is quite capable of dealing with the full output of any modern blooming

Table I

PARTICULARS OF HOT BLOOM AND SLAB SHEARS

Supplied 1945–1950

Section to Cut, in.	Area of Section, sq. in.	Nominal Blade Load, tons	Stroke of Blade, in.	Cutting Rate/min.	Type	System	Drive	Motor, h.p.	Motor Speed, r.p.m.	Crank-shaft Speed, r.p.m.
16 × 16	256	1200	21	3	Down- and up-cutting	Direct electric	Triple-reduction two-speed gear, built in shear frame. No fly-wheels	2 at 200	200/700	
2 at 5 × 5	50	600		9·5						
12 × 12	144	700	16½	5	Down- and up-cutting	Direct electric	Triple-reduction two-speed gear, built in shear frame. No fly-wheels	350/650	300/900	2·5/7·5
2 at 5 × 5	50	350		9						6·02/18·05
12 × 12	144	700	16½	5	Down- and up-cutting	Direct electric	Triple-reduction two-speed-gear, built in shear frame. No fly-wheels	350/650	300/900	2·5/7·5
2 at 5 × 5	50	350		9						6·02/18·05
5 × 55 8 × 34	275	900	12 (max.)	3 Full load cuts	Adjustable up-cutting	Hydraulic	1–2 in. × 12 in. pump, 1–100 gal. air hyd. accumulator, 2 tons/sq. in.	175	585	
16 × 16	256	1350	20		Down- and up-cutting undercrank	Direct electric	Double-reduction gear with two input shafts. Spindle connects to shear. No flywheels	2 at 500/1000	375/750	9·15/18·29
12½ × 48	600									
14 × 14	196	1350	20		Down- and up-cutting undercrank	Direct electric	Double-reduction gear with two input shafts. Spindle connects to shear. No flywheels		375/750	9·15/18·29
12½ × 48	600									
12 × 14	168	700	16·8 (theoretical)		Down- and up-cutting	Steam-hydraulic	71 in. and 9 in. × 75 in. S.H. intensifier S.W.P. 90 lb./sq. in. H.W.P. 2½ tons/sq. in.			
18·54	972				Down- and up-cutting	Hydraulic	Pump and air-loaded accumulator			

mill, and it is only in some continental works that more than one unit has been considered necessary. In these cases one shear deals with the larger sections and one or two other units deal with the small sections. Typical examples of these various layouts are shown in Figs. 19–21.[3]

The distance between the mill and the shear is usually determined by the maximum length of the piece to be rolled, and should be sufficient to allow the piece to run clear of the manipulator side guards before entering the shear. This enables rolling to proceed without interruption, even in the event of minor delays at the shear, and necessitates the shear being from 120 to 160 feet from the mill.

The location of the shear relative to the barrel of the mill roll depends on the position of the finishing passes in the roll. Ideally, the piece should run straight out from the rolls into the centre of the shear, but where a number of sections are being rolled this is not possible, and the position of the shear is therefore a compromise.

CHOICE OF SHEAR

The choice of shearing equipment for new installations is determined by the maximum size of the piece to be cut, by the frequency of cutting, and by economic considerations. Local circumstances are also important, especially in so far as plant layout and availability of services are concerned, the latter considerations applying more particularly to the installation of new shearing equipment in existing works.

Present-day trends are now clearly defined, and as the main points of difference have already been established, the problem of choosing the most suitable shear for a particular application is simplified.

Table I—(*continued*)

Shear Gauge						Crop Disposal System	Crop Pushers (Back)					
Capacity	Type	Motors					Type	Location	Stroke, in.	Speed, in./sec.	Motor	
		Setting		Raising								
		h.p.	r.p.m.	h.p.	r.p.m.						h.p.	r.p.m.
2 ft. 4 in.–10 ft.	Gun-barrel type with automatic relieving gear operated from shear	15	500	15	500	First two rollers on outgoing side shift to form gap. Chute with switch leads to one of two buckets	Gun-barrel type with fixed cam raising gear	Over ingoing table		4·54	15	500
3 ft.–17 ft.	Gun-barrel type, with automatic relieving gear operated from shear	20	600	20	600	First two rollers on outgoing side shift to form gap. Chute leads to buckets on revolving table	Gun-barrel type with fixed cam raising gear	Over ingoing table	40½ Operative 70 Total	4·28	20	600
	None					First two rollers on outgoing side shift to form gap. Chute with switch leads to one of two buckets	Gun-barrel type with fixed cam raising gear	Over ingoing table	40½ Operative 70 Total	4·28	20	600
6 ft. 3 in.–16 ft. 6 in.*	Gun-barrel type no separate provision for relieving	25	650	25	650	Crops pushed sideways off table. Chute with switch leads to one of two buckets	Rack and pinion	Mounted in shear frame and rising with bottom shear blade	65	7·6	10	725
4 ft. 6 in.–20 ft.	Lifting-stop type on rails over table, 2 screws	50	575	35	625	Pull-back table on outgoing side. Crops chuted back. Sideways trap-door release to one bucket	Overhead carriage type, automatic retracting		171	42	35	625
5 ft.–20 ft.		50	575	35	625	Pull-back table on outgoing side. Crops chuted back. Sideways trap-door release to mobile skip	Overhead carriage type, automatic retracting		171	42	35	
2 ft. 6 in.–18 ft.	Gun-barrel type						Grass hopper	Mounted on ingoing side of shear frame	63 Operative			

* These particulars apply to front and back crop pushers

Particulars of shears supplied by the main British builder of rolling-mill machinery during the period 1945–1950 are given in Table I.

Direction of Cutting

Practically all shears now being built (it is almost safe to say all shears) are of the up-cutting or down- and up-cutting types. Among their many advantages over other designs are cleaner cutting and simplification of ancillary mechanical equipment by elimination of the depressing table.

Method of Developing Cutting Power

With the exception of plants based on steam, or plants having supplies of cheap waste-heat steam available, all shears use electricity as their primary source of power.

For shears having blade loads up to 1500 tons, the electric drive using variable-speed reversible motors through reduction gearing and toggle or lever systems is almost universal. For smaller-capacity shears of this type, continuously running motors with flywheels and disengaging clutches are sometimes used.

Where the blade load is greater than 1500 tons, the use of mechanical methods for developing the cutting load is not, as a rule, an economic proposition, and the hydraulically operated shear is the most suitable unit for these applications. The hydraulic power is generated by reciprocating or rotary pumps, feeding directly into the cylinder(s) of the shear or, as is more usual where the number of cuts permits, through a weight- or air-loaded accumulator system.

An alternative source of hydraulic power for such applications is the electro-hydraulic intensifier. Although this is suitable from an operational standpoint,

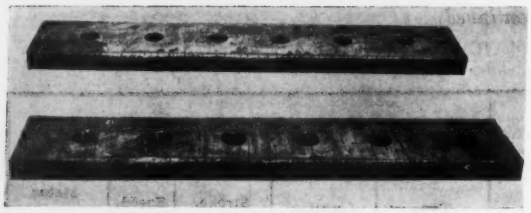


Fig. 22—Blades for 42 in. × 10 in. steam-hydraulic down-cutting hot bloom and slab shear, after six months' service

it necessitates large-capacity electrical equipment, as in the case of the direct-coupled pumping units.

Construction of Frame

The open-sided shear has become increasingly popular in recent years, and in European works is standard practice for blade loads up to 1500 tons. Up to the present, however, most American shears have used the closed-frame construction.

The open-sided shear has many points in its favour ; among these are greater accessibility to blades, simplified construction of roller tables by allowing the bearings and driving gears to be located outside the shear frame, economy in space where site conditions necessitate side movement of the piece immediately after cutting, and greater ease in the handling of crop ends.

Economics

A close analysis of the installation costs of the various types of shear is scarcely possible, owing to the effect of local conditions. It can be shown, however, that the mechanical shear with variable-speed reversible motor drive is more expensive than the hydraulically operated unit of the same capacity, using steam or compressed air as the primary power medium. If, however, a proportion of the cost of steam-raising or compressing plant is included in the cost of such a shear, the difference in the overall cost of the shears is considerably reduced. The question then becomes one of upkeep and operating costs, and, in the same way that the electric prime mover has superseded the steam engine for rolling-mill drives, the electrically driven shear has superseded the hydraulically operated unit.

SHEAR BLADES

Blades are a major consideration in the economics and operation of shearing, and considerable attention has therefore been devoted to improving their performance. Practice varies from one works to another, and Table II gives particulars of the blades of some British shears ; these deal with more than 90% of the steel rolled in this country.

A set of blades which has given excellent service is illustrated in Fig. 22. These blades were fitted to a 42 in. × 10 in. steam-hydraulic down-cutting bloom and slab shear, and gave six months' service from each cutting edge.

TYPICAL SHEARING EQUIPMENT

To complete this brief review of hot bloom and slab shears, descriptions are given of some of the more interesting items of equipment which have been developed for this duty.

60 in. × 13 in. Steam-Hydraulic Down-Cutting Hot Slab Shear

Typical of many large shears installed in Britain during the years following the First World War is the shear illustrated in Fig. 23. It possesses no outstanding features, although it incorporates the usual devices for efficient cutting, *i.e.*, stop measuring gear, holding-down gear, crop-end pusher, and pusher for discharging the crop ends sideways from the delivery table into skips arranged alongside. An added refinement in this plant is the provision of a short depressing table, on the entry side of the shear, mounted on springs. This relieves the roller table of the load-

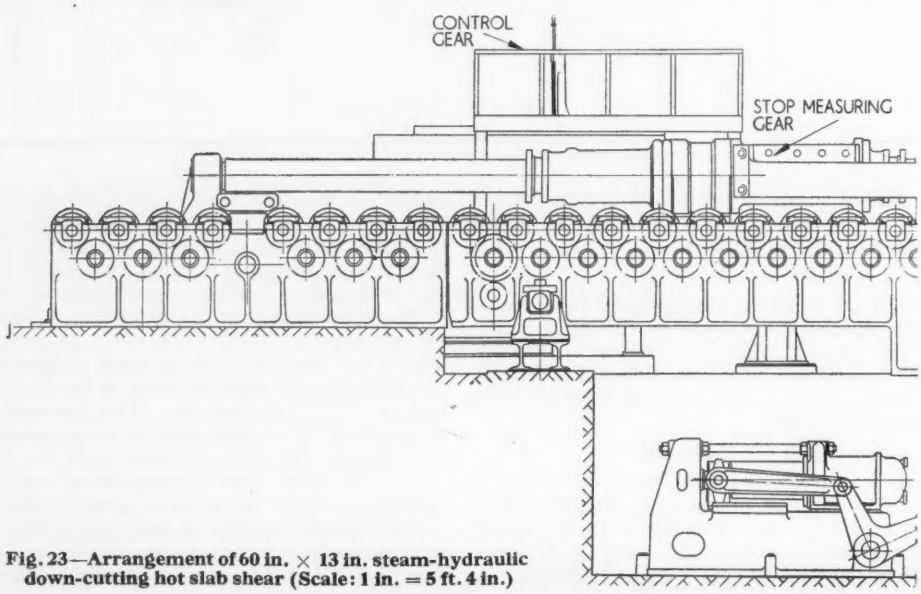


Fig. 23—Arrangement of 60 in. × 13 in. steam-hydraulic down-cutting hot slab shear (Scale: 1 in. = 5 ft. 4 in.)

ing induced during cutting, and reduces the danger of failure of mechanical parts.

14 in. × 14 in. Hydraulic Down- and Up-Cutting Hot Bloom Shear

This shear operates in conjunction with a 36-in. reversing blooming mill producing alloy and ordinary quality steel bars, and is capable of cutting blooms up to 14 in. × 14 in. and of exerting a maximum pressure of 1000 tons on the blades. It is supplied with water at a maximum pressure of 3 tons/sq. in. from a triple-power hydraulic intensifier unit, which takes its primary power from the works hydraulic system at a pressure of 750 lb./sq. in. The shear has single-lever control and the usual devices for economizing in the use of pressure water ; Fig. 24 shows the valve and pipe diagram for the installation. Crop-end removal is through a gap in the roller table and over a chute into skips mounted on a turntable ; this system assists in the segregation of the various grades of alloy scrap.

40 in. × 10 in. Steam-Hydraulic Down- and Up-Cutting Hot Bloom and Slab Shear

This shear is very similar to the one referred to above, but is supplied with high-pressure water at 3 tons./sq. in. from a steam-hydraulic intensifier unit. The shear is capable of exerting a maximum pressure of 1400 tons on the blades, and of cutting blooms up to 21½ in. × 16½ in. and slabs up to 40 in. wide × 10 in. thick when working with steam at a pressure of 150 lb./sq. in. It has single-lever control, and is fitted with hydraulic lifting and return cylinders for the top apron and bottom bolster respectively. The arrangement of the shear proper is shown in Fig. 25, whilst Fig. 26 shows the valve and pipe diagram for the installation. A hydraulically operated crop-end pusher (Fig. 12) is fitted to the front of the shear, and the pieces of scrap pass through a gap in the delivery roller table on to a chute, and thence into skips mounted on a turntable.

Lamberton 12 in. × 12 in. Electrically Driven Down-Cutting Hot Bloom Shear

This shear was designed especially for dealing with alloy steels, and, although the largest bloom to be cut is only 12 in. × 12 in., is capable of exerting a maximum pressure of 1500 tons on the blades. The shear is driven by two motors, each of 200 h.p., through double-reduction gearing to the camshaft, with Ward-Leonard control giving speeds of 3–9 strokes per minute. For each cut the motors are started by the operator and are stopped automatically by means of limit switches, dynamic and mechanical braking being used to ensure that the shear halts at the top dead-centre position. The shear is fitted with holding-down gear, stop measuring equipment, and crop-end pusher, all electrically operated ; Fig. 27

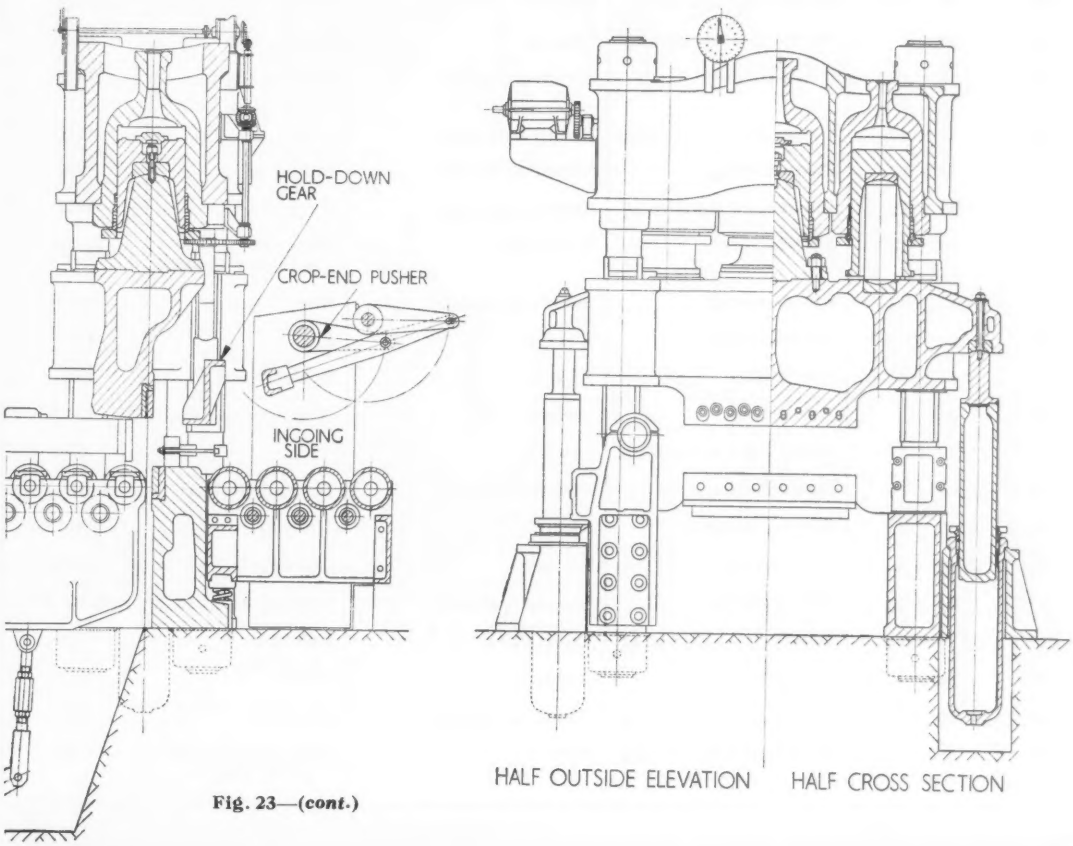


Fig. 23—(*cont.*)

Table II

PARTICULARS OF HOT BLOOM AND SLAB SHEARS IN GREAT BRITAIN

Plant	Maximum Section Cut, in. × in.	Type of Shear	Type of Drive	Maker	Year of Manufacture
1	18 × 9	Down-cutting	Steam	Davy	1888
2	12 × 12	Up-cutting	Steam-hydraulic	Breur and Schumacher	About 1905
3	36 × 14	Up-cutting	Steam-hydraulic	Davy	1906
4	38 × 14	Up-cutting	Steam-hydraulic	Davy	1906
5	32 × 10 or 18 × 16	Down- and up-cutting	Hydraulic (direct or intensified)	Davy	1910
6	18 × 12	Down-cutting	Steam-hydraulic	Lamberton	1913
7	66 × 18	Down-cutting	Steam-hydraulic	Davy	1913
8	10 × 10	Side-cutting	Electric	Davy	1916
9	40 × 10	Down-cutting	Steam-hydraulic	Davy	1917
10	16 × 10	Down-cutting	Hydraulic	Bruce Peebles	1918
11	180 sq. in.	Down-cutting	Hydraulic for 6 in. × 6 in.; steam-hydraulic for larger sections	Davy	1918
12	10 × 10	Down- and up-cutting	Electric	Davy	1918
13	18 × 6	Down- and up-cutting	Electric	Davy	1918
14	64 × 16 or 43 × 20	Down-cutting	Steam-hydraulic	Duncan Stewart	1918
15	12 × 12	Down- and up-cutting	Steam-hydraulic	Davy	1920
16	12 × 12	Down-cutting	Steam-hydraulic	Davy	1920
17	54 × 18	Down- and up-cutting	Steam-hydraulic	Davy	1921
18	10 × 10	Side-cutting	Hydraulic	Davy (Bolckow Vaughan design)	1922
19	42 × 12	Down-cutting	Steam-hydraulic	Davy	1924
20	7 × 6	Down-cutting	Electric	Sack	1924
21	16 × 8	Up-cutting	Electric	Schloemann	1933
22	8 × 8	Up-cutting	Electric	Schloemann	1933
23	12 × 12	Down- and up-cutting	Electric	Sack	1935
24	42 × 10	Down-cutting	Steam-hydraulic	Duncan Stewart	Rebuilt 1936
25	49 × 4	Down-cutting	Electric	United	1937
26	40 × 5	Up-cutting	Electric	Loewy	1938
27	60 × 13	Down-cutting	Steam-hydraulic	Duncan Stewart	Rebuilt 1944
28	14 × 14	Down- and up-cutting	Hydraulic	Colvilles	1945
29	16 × 16	Up-cutting	Electric	Loewy	1946
30	40 × 10	Down- and up-cutting	Steam-hydraulic	Colvilles	1946
31	$16\frac{1}{2} \times 16\frac{1}{2}$	Down- and up-cutting	Electric	Davy and United (Sack design)	1948

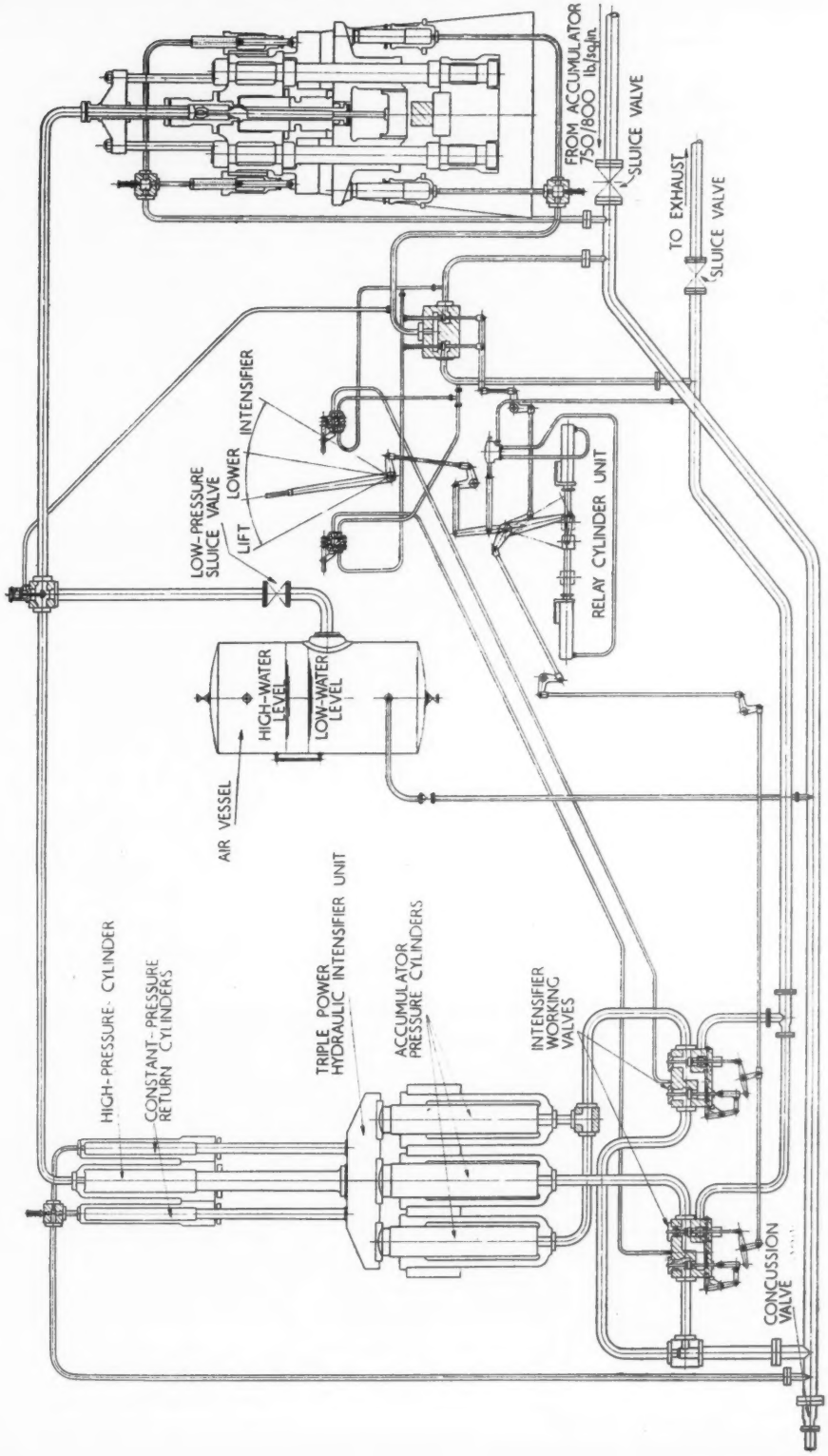


Fig. 24.—Valve diagram for 14 in. × 14 in. hydraulic down- and up-cutting hot bloom shear

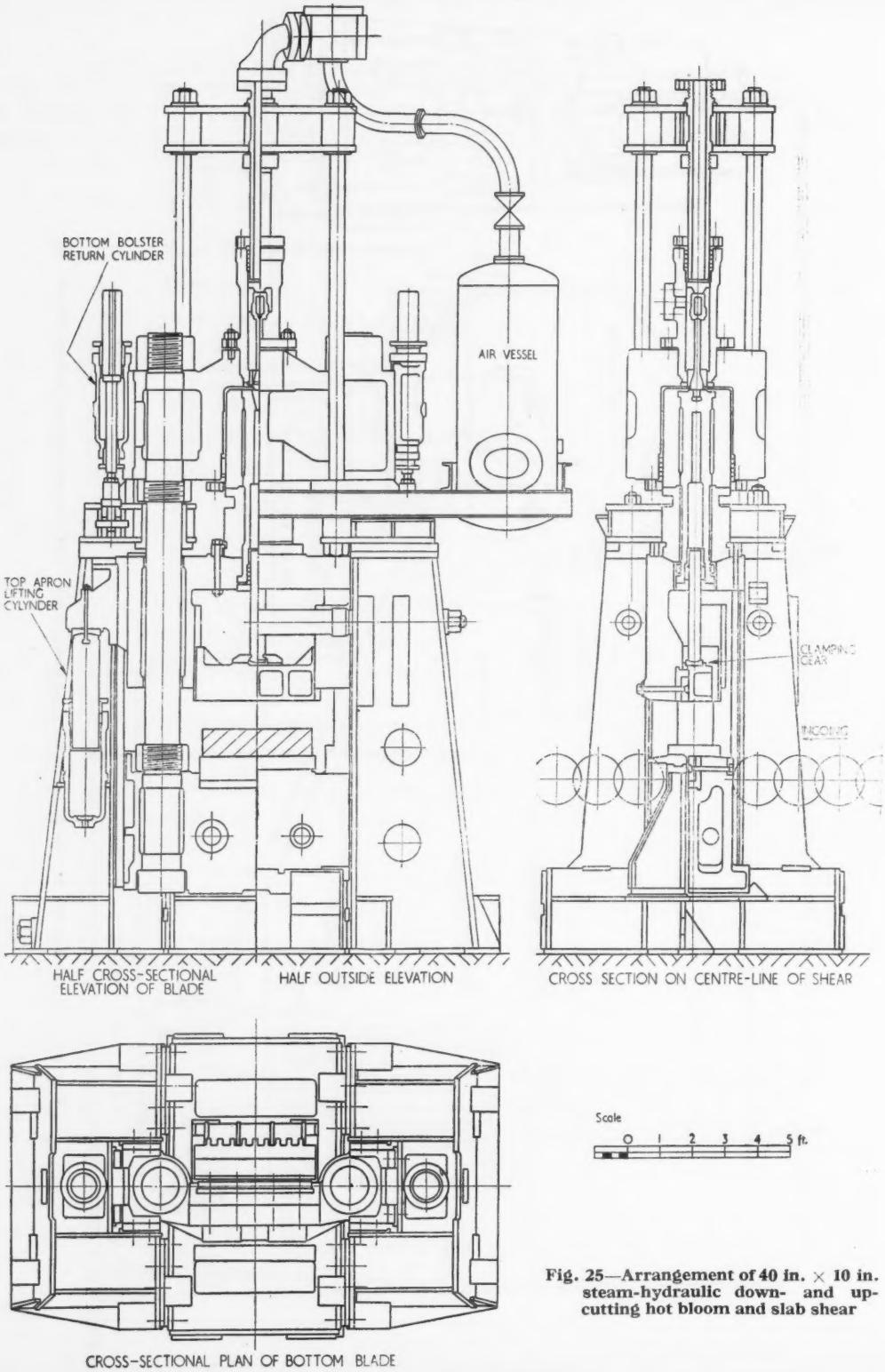


Fig. 25—Arrangement of 40 in. × 10 in. steam-hydraulic down- and up-cutting hot bloom and slab shear

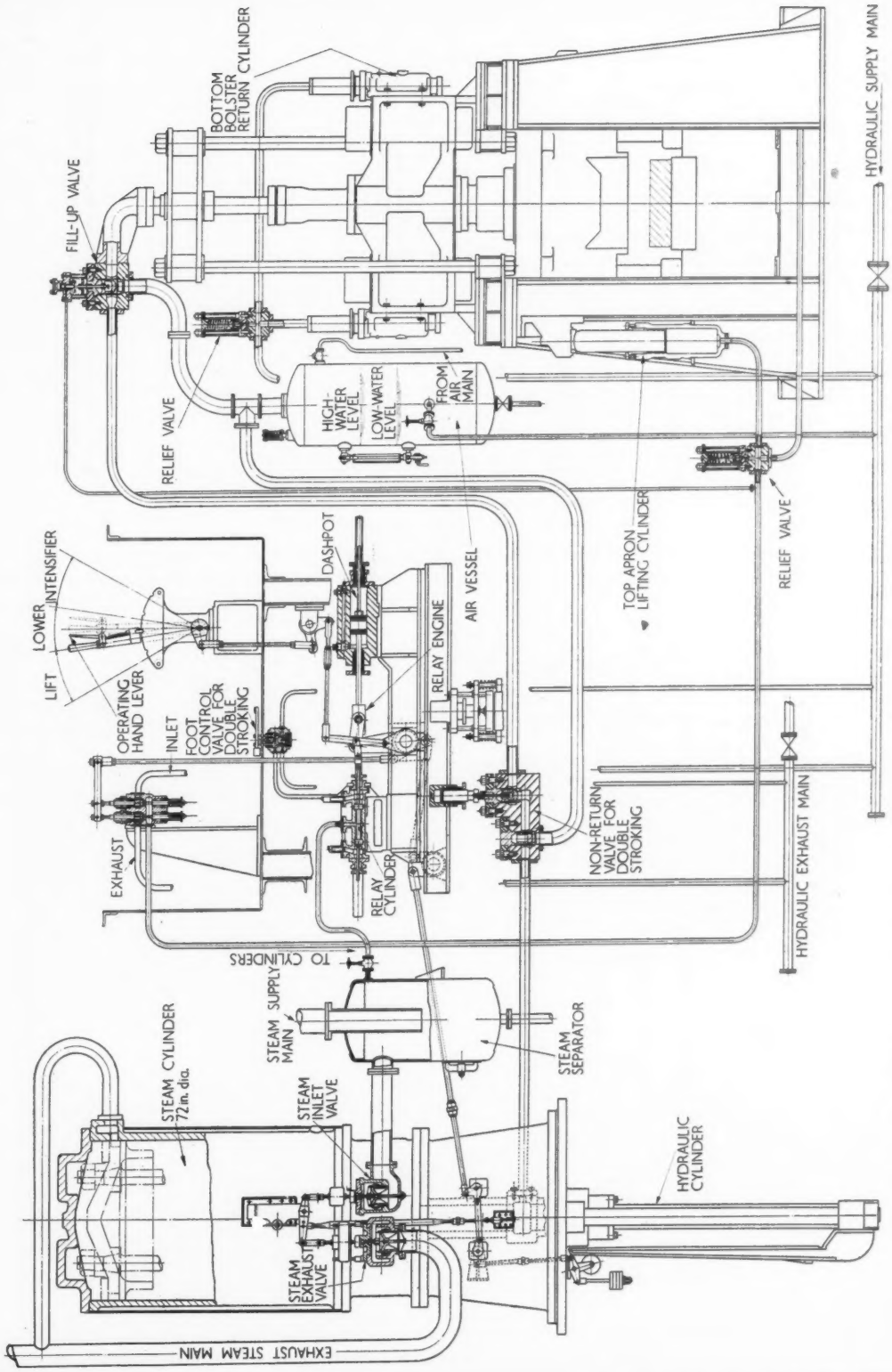


Fig. 26—Valve diagram for 40 in. × 10 in. steam-hydraulic down- and up-cutting hot bloom and slab shear

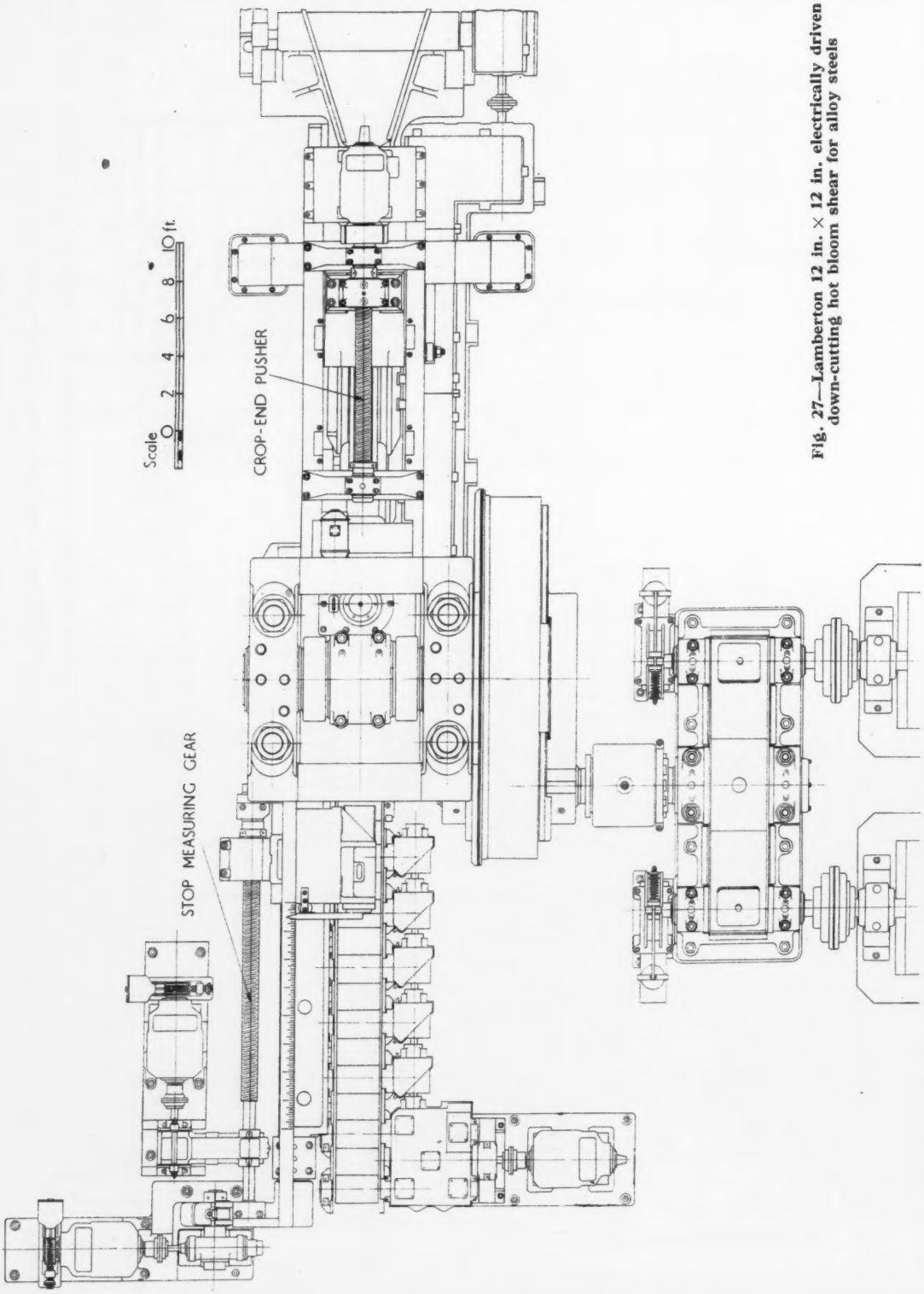


Fig. 27.—Lamberton 12 in. × 12 in. electrically driven down-cutting hot bloom shear for alloy steels

shows a plan view of the installation, and Fig. 28 is a cross-sectional elevation illustrating the holding-down gear and the crop-end pusher.

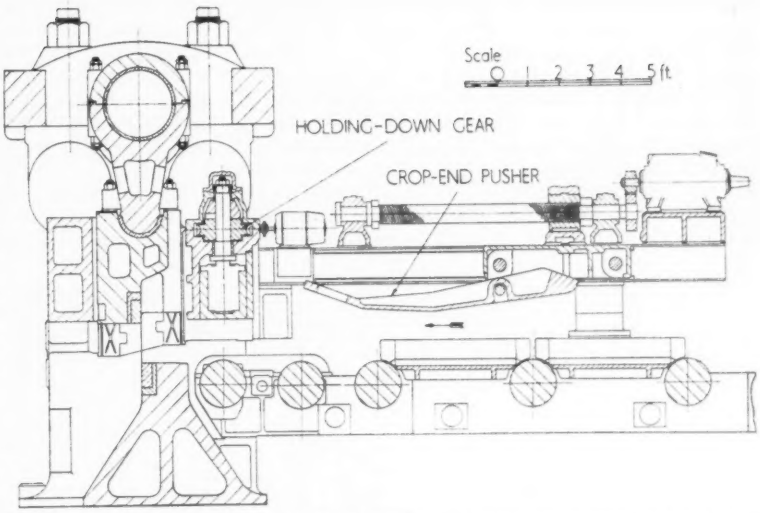


Fig. 28—Lamberton 12 in. × 12 in. electrically driven down-cutting hot bloom shear for alloy steels. Cross-section showing holding-down gear and crop-end pusher

United 66 in. × 22 in. Hydraulic Up-Cutting Hot Slab Shear

This shear, which forms part of one of the largest-capacity American slab-producing units, is capable of exerting a maximum pressure of 3000 tons on the blades, and of cutting slabs up to 66 in. wide × 22 in. thick. Hydraulic power at 6000 lb./sq. in. is supplied to the single-pressure cylinder by three 400-h.p. rotary pumps, the number of pumps operating at any time depending on the speed of cutting desired ; during the intervals between cuts the pumps are idling or unloading. The overall shear opening is 76 in. × 27 in., and the maximum stroke of the bottom blade is 27½ in. The apron carrying the top blade can be raised or lowered, by means of an electrically operated screwing gear, to suit the height of section being cut, thus minimizing the use of pressure water and the time which might otherwise be lost in idle stroking.

For disposing of the scrap, which may amount to as much as 20,000 tons per month, the table behind the shear is arranged to retract a distance of 24 in., so that the crop ends can be discharged on to a heavy chain-type conveyor which delivers them on to a scrap bed. Here they are segregated by means of a 10-ton stiff-leg crane, for return to the melting shop.

Davy-United 12 in. × 12 in. Electrically Driven Down- and Up-Cutting Hot Bloom Shear

This shear, which is illustrated in Figs. 29 and 30, is capable of exerting a maximum pressure of 700

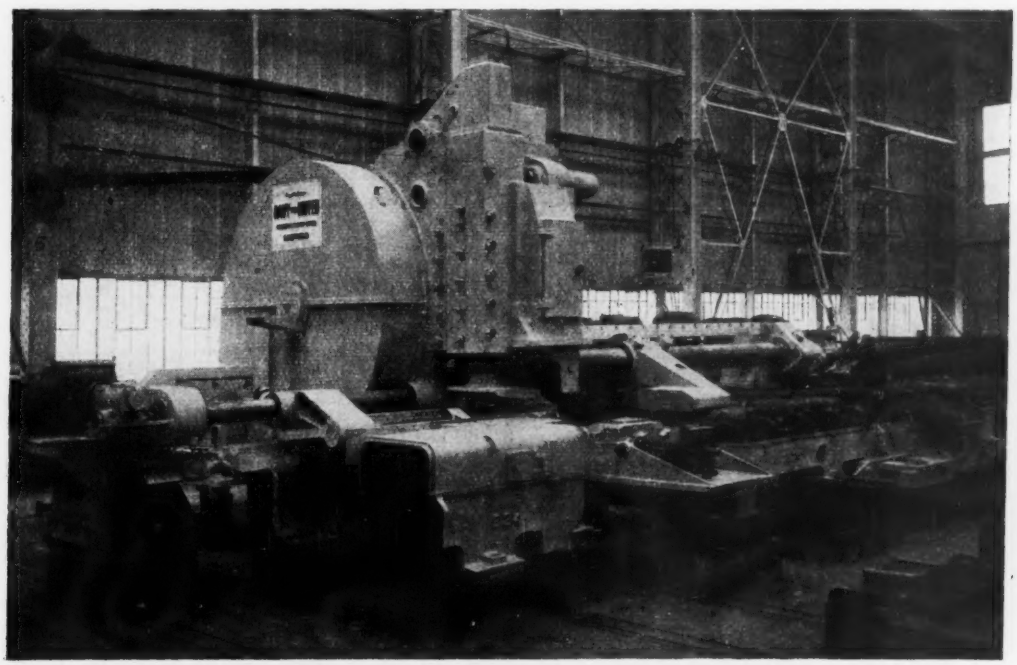


Fig. 29—Davy-United 12 in. × 12 in. electrically driven down- and up-cutting hot bloom shear. Erection view showing crop-end pusher and stop measuring gear

tons on the blades, and of cutting blooms up to 12 in. × 12 in. It incorporates effective means for dealing with scrap, the crop-end pusher being of special interest. This is clearly shown in the illustrations, and comprises a pushing head carried at the end of an extension bar from a lever mounted on a heavy spindle. The lever can be traversed backwards and forwards along the spindle, which is located alongside the ingoing roller table, by means of an internal screw. A pin is attached to the back of the lever, and moves in a guide slot formed in the spindle support bracket. This slot is shaped so that the lever, as it commences its stroke, is first lowered to within a short distance of the top of the table, and then moves forward in a straight line to push the crop end through the shear. On the return stroke the motion is reversed, and the lever is tilted upwards to clear the roller table, so allowing the following bloom to pass through.

Movable rollers are provided so that the crop ends can fall through the table on to an inclined plate and thence into skips carried on a turntable.

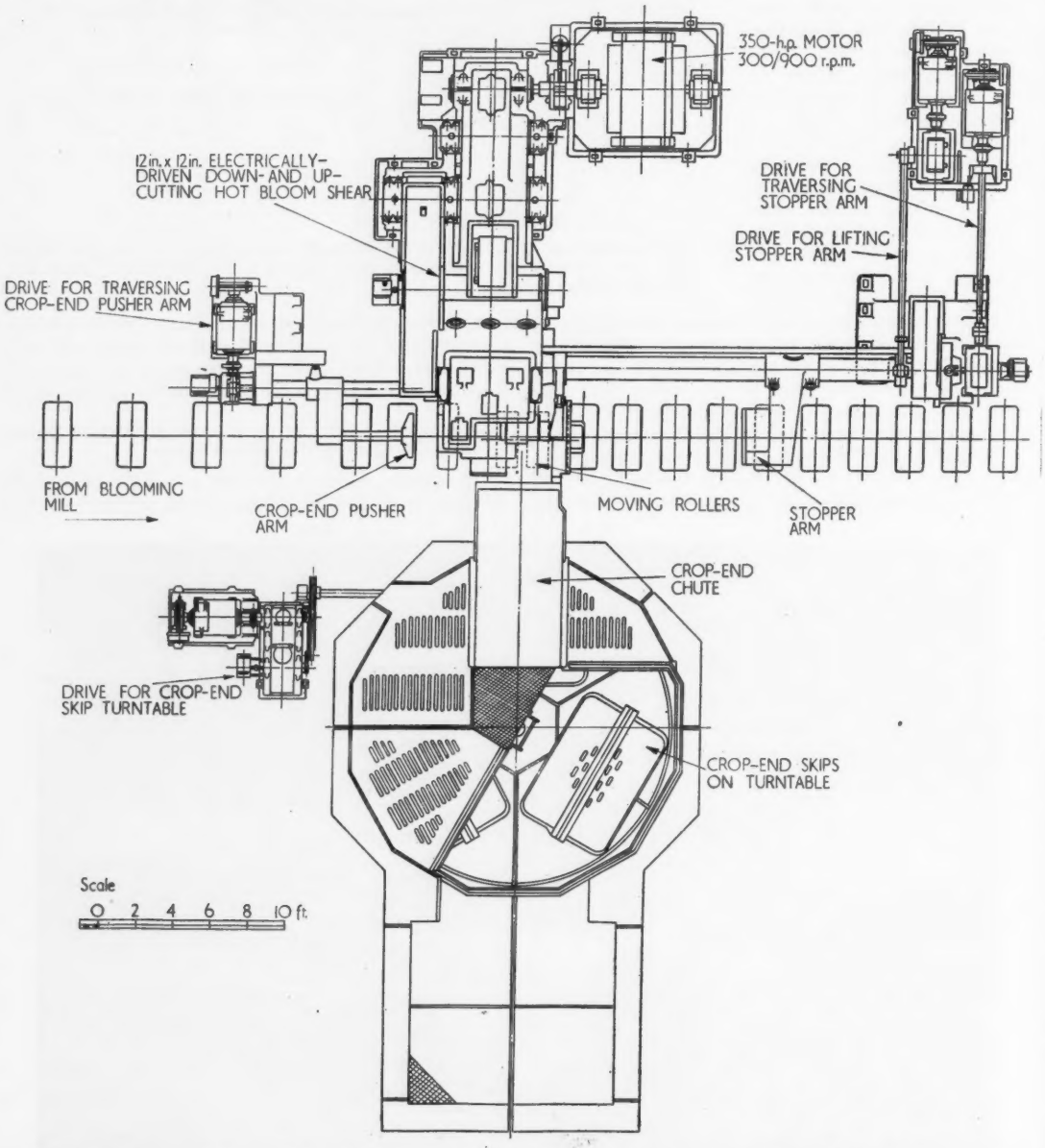

350-h.p. MOTOR
300/900 r.p.m.
12 in. x 12 in. ELECTRICALLY-DRIVEN DOWN- AND UP-CUTTING HOT BLOOM SHEAR
DRIVE FOR TRAVERSING STOPPER ARM
DRIVE FOR LIFTING STOPPER ARM
DRIVE FOR TRAVERSING CROP-END PUSHER ARM
FROM BLOOMING MILL
CROP-END PUSHER ARM
MOVING ROLLERS
STOPPER ARM
CROP-END CHUTE
DRIVE FOR CROP-END SKIP TURNTABLE
CROP-END SKIPS ON TURNTABLE
Scale
0 2 4 6 8 10 ft

Fig. 30—Layout of Davy-United 12 in. × 12 in. electrically driven down- and up-cutting hot bloom shear, showing crop-end handling equipment

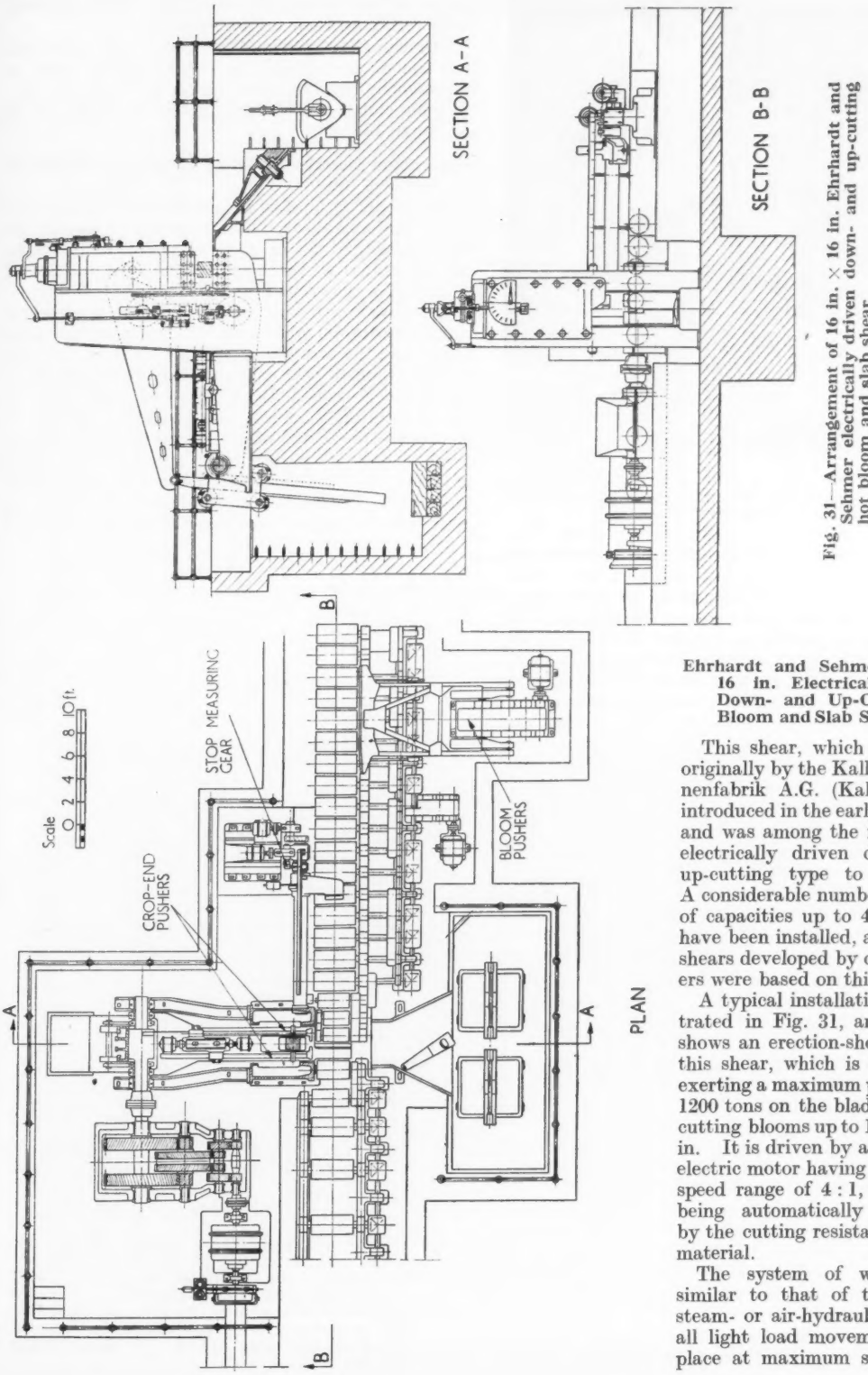


Fig. 31—Arrangement of 16 in. × 16 in. Ehrhardt and Sehmer electrically driven down- and up-cutting hot bloom and slab shear

Ehrhardt and Sehmer 16 in. × 16 in. Electrically Driven Down- and Up-Cutting Hot Bloom and Slab Shear

This shear, which was made originally by the Kalker Maschinenfabrik A.G. (Kalmag), was introduced in the early twenties, and was among the first of the electrically driven down- and up-cutting type to be built. A considerable number of units, of capacities up to 400 sq. in., have been installed, and certain shears developed by other makers were based on this design.

A typical installation is illustrated in Fig. 31, and Fig. 32 shows an erection-shop view of this shear, which is capable of exerting a maximum pressure of 1200 tons on the blades, and of cutting blooms up to 16 in. × 16 in. It is driven by a reversible electric motor having a variable speed range of 4 : 1, the speed being automatically regulated by the cutting resistance of the material.

The system of working is similar to that of the earlier steam- or air-hydraulic shears ; all light load movements take place at maximum speed, and

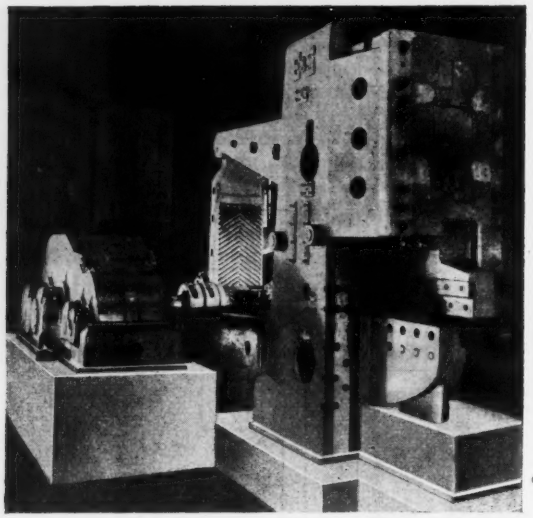


Fig. 32—Erection view of 16 in. × 16 in. Ehrhardt and Sehmer electrically driven down- and up-cutting hot bloom and slab shear

the speed decreases automatically during cutting, in proportion to the increase in resistance.

The motor is coupled through a totally enclosed triple-reduction gear unit to the fulcrum shaft of the lower lever, to which the bottom blade is directly attached. The apron carrying the top blade moves in guides in the main frame, and is connected to the front end of the upper lever. A pinion mounted on the lower fulcrum shaft engages with a toothed rack which is connected to the rear end of the upper lever. Both levers are coupled together by means of heavy links, and the system is so arranged that all primary stresses induced during cutting are self-contained, so that the shear frame is completely relieved of these.

To minimize idle stroke and consequent loss of power consumption and time, the top apron can be adjusted mechanically to suit the height of section being cut, and the driving motor can be operated to give the minimum stroke required to effect the cut.

The installation shown in Fig. 31 incorporates stop measuring gear, bloom pusher, and two crop-end pushers, all electrically operated. The front and back end crops are discharged sideways, by one or other of the two pushers, over an inclined plate into skips arranged in a pit alongside the shear ; a switchplate is provided so that as one skip is being filled the other can be emptied.

Method of Operation—When the motor is started, the pinion engaging the toothed rack induces an upward movement at the rear end of the upper lever, and the top blade apron moves down on to the piece until its motion is arrested. The continued upward movement of the rear end of the upper lever lifts upwards the front end of the lower lever carrying the bottom blade, owing to the connecting links between the upper and lower levers ; this movement produces the up-cutting stroke.

Limit switches are provided for the automatic reversal of the driving motor, so that after the completion of the cutting operation the blades immediately return to their original position.

Although the reversing-type motor with start and stop control is desirable for large-capacity units, a continuously running motor with flywheel and disengaging clutch can be used for shears cutting billets and small blooms.

Schloemann Electrically Driven Up-Cutting Hot Bloom and Slab Shear

This shear is similar in general principle to the earlier Kalmag shear, but makes use of crankshaft and connecting rod in place of pinion and rack to impart motion to the lever system ; the method of operation is shown in Fig. 33.

The shear is of the up-cutting type, the top blade *A* being adjustable to suit the thickness of the piece being cut ; the position of the top blade is indicated on a dial, and adjustment can be effected by the shear operator. So long as the blooms and slabs to be cut are of uniform thickness, the top blade remains in its fixed position and makes no up or down motion.

Suspended on the top blade apron *B* is a system of levers, of which the upper lever *C* is supported in the apron. The lower lever *D* is designed as a swinging lever, and both upper and lower levers are connected

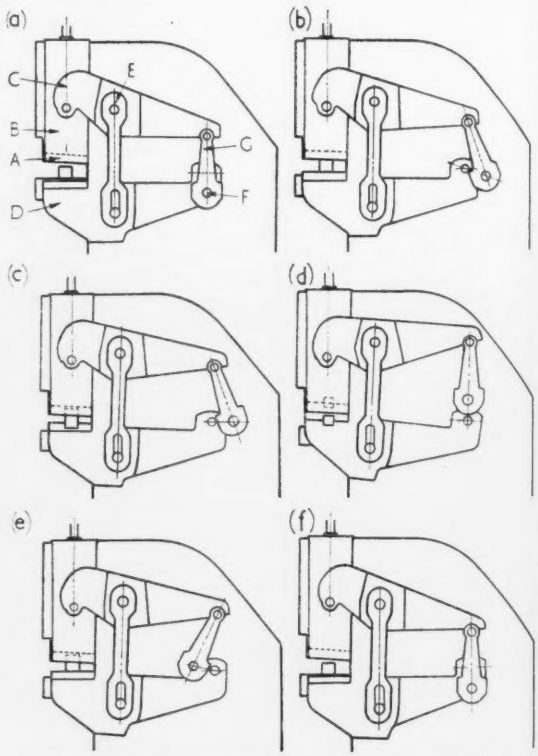
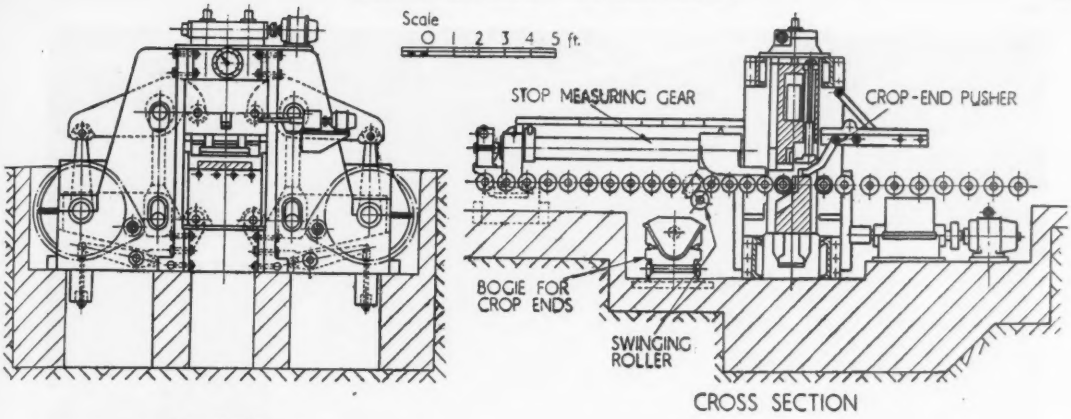


Fig. 33—System of operation of Schloemann electrically driven up-cutting hot bloom and slab shear. (*a*) Ready to take the bloom. Maximum gap. (*b*) Commencement of cut. (*c*) During the cut. (*d*) End of cut; cut off bloom may run out. (*e*) After the cut. The descending bottom blade lever deposits the bloom on the table rollers. (*f*) Shear ready for next cut



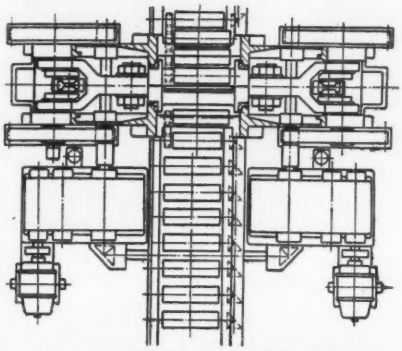


Fig. 34—Arrangement of Schloemann electrically driven down- and up-cutting hot bloom and slab shear

by a tie rod *E* and are operated by a connecting rod *G* mounted on the crankshaft *F*.

The shear is driven by two electric motors through totally enclosed reduction gearing, and the power is transmitted by the connecting rod to the system of levers. The motors are started by the shear operator, and are stopped automatically by limit switches and counter-current braking ; when cutting heavy sections the crankshaft makes one complete revolution and then stops.

An electrical control device is fitted which enables the crankshaft to make partial rotations, thus economizing in time and power when cutting blooms and slabs of reduced thickness. The crankshaft makes a rotation of 180°, and after each cut the motors are reversed for the next cut.

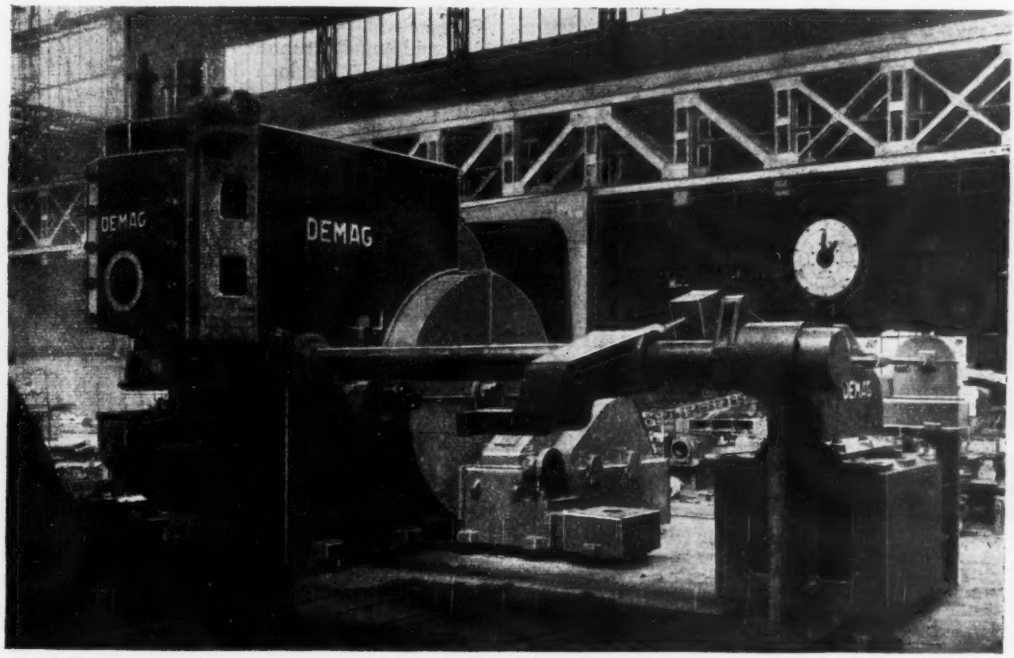


Fig. 35—Demag 52 in. × 6 in. or 14 in. × 14 in. electrically driven down- and up-cutting hot bloom and slab shear. Erection view showing stop measuring gear

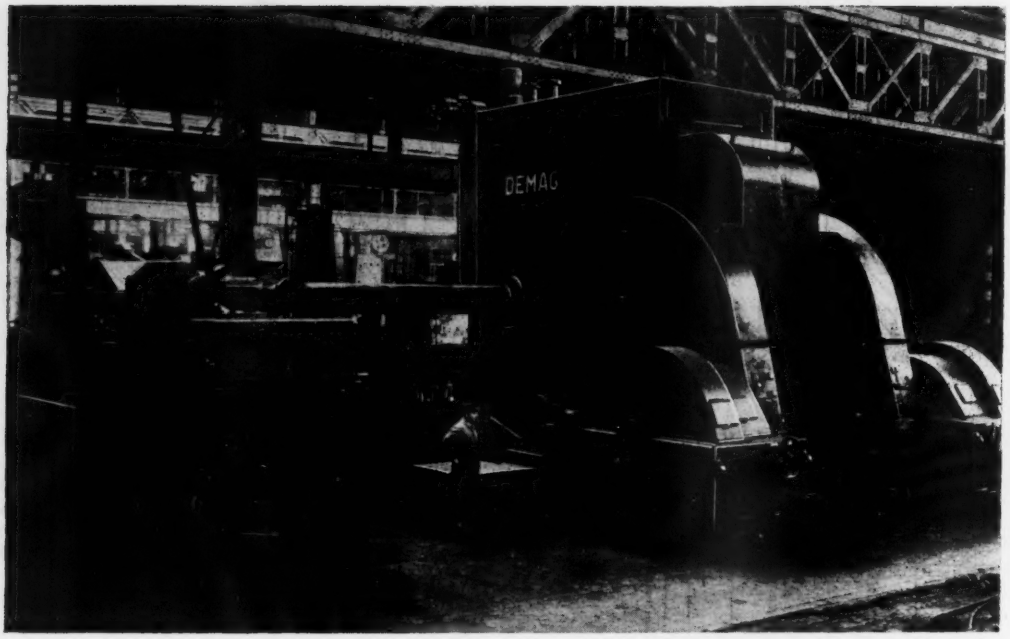


Fig. 36—Demag 52 in. × 6 in. or 14 in. × 14 in. electrically driven down- and up-cutting hot bloom and slab shear. Erection view of shear from rear, showing twin drives

A holding-down gear is provided close up to the blades, to avoid movement of the material during cutting. Crop-end removal is generally effected in the same manner as on the Kalmag shear ; two pushers are mounted in the lower lever and discharge the front and back crop ends over the table and an inclined plate, into skips located in a pit at the side of the table.

All shears of this type for large sections are driven by variable-speed reversible motors having start and stop control ; however, where the expense of such equipment is not justified, as for shears of smaller sections and outputs, continuously running motors with flywheels may be used. Electro-magnetic disengaging clutches are then incorporated in place of the more usual jaw type, thus ensuring easy engagement and smooth running.

Where the blade load does not exceed 1200 tons,

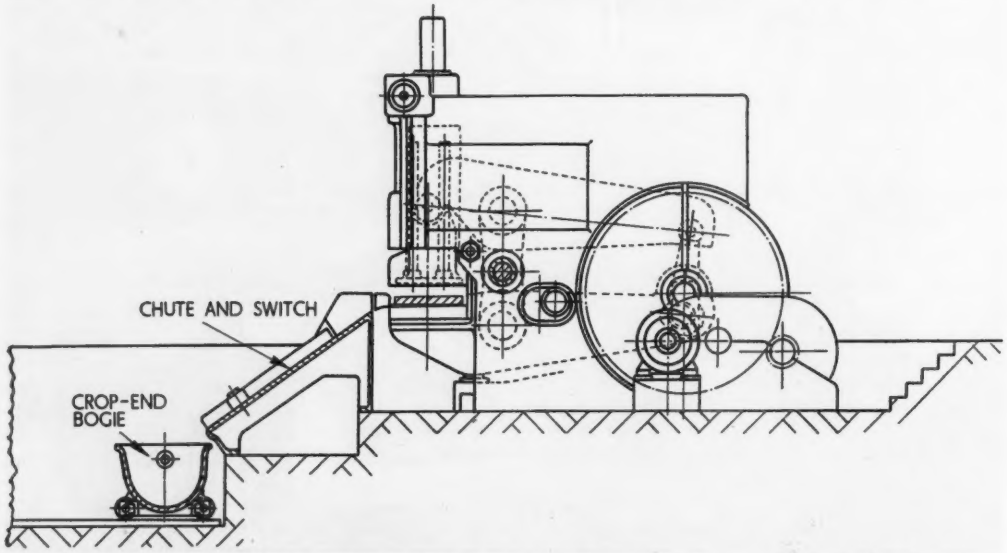


Fig. 37—Demag 52 in. × 6 in. or 14 in. × 14 in. electrically driven down- and up-cutting hot bloom and slab shear. Elevation of shear showing crop-end chute and bogie (Scale : 1 in. = 10 ft.)

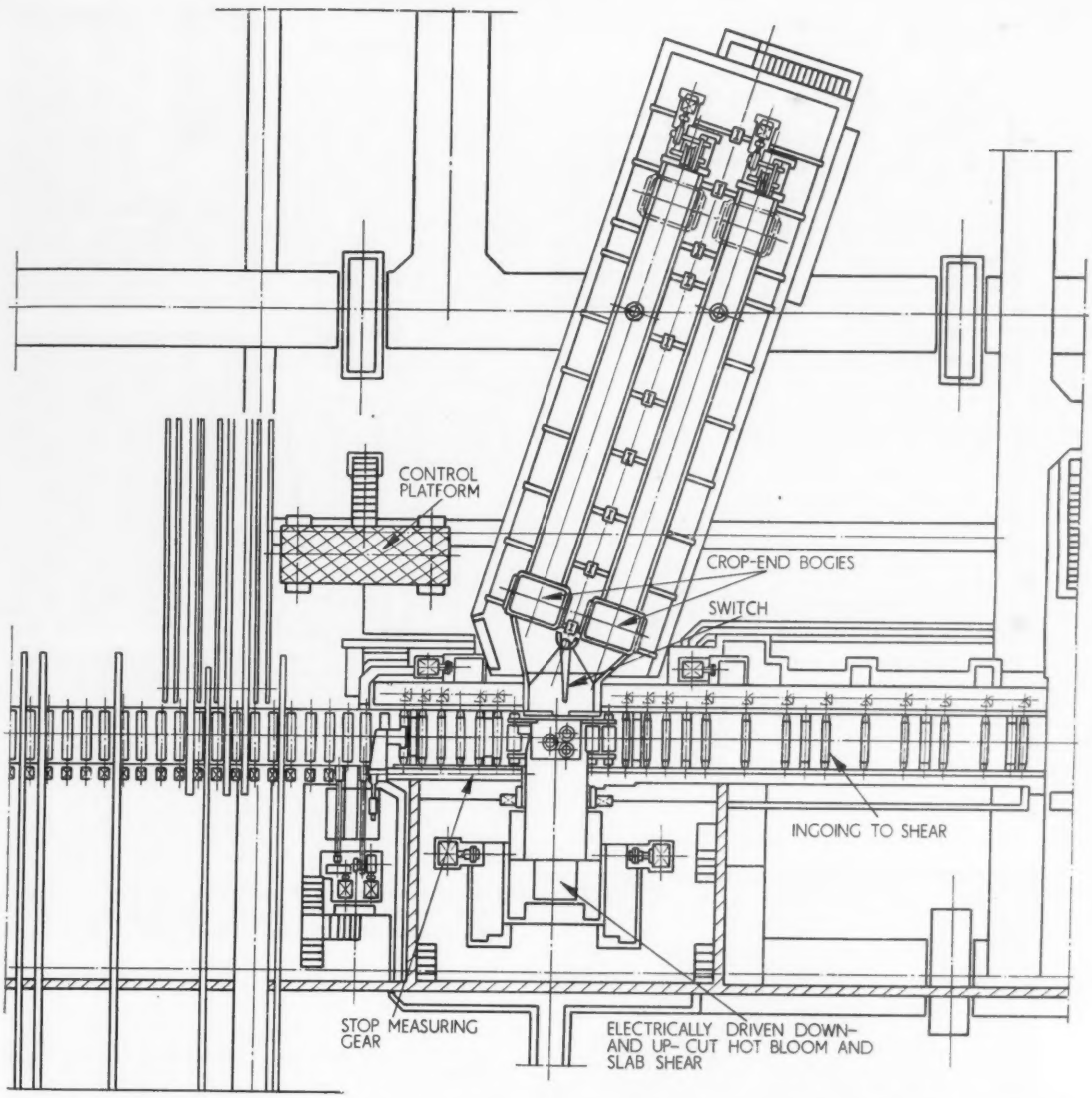


Fig. 38—Demag 52 in. × 6 in. or 14 in. × 14 in. electrically driven down- and up-cutting hot bloom and slab shear. Layout showing crop-end disposal equipment (Scale : 1 in. = 21 ft. 4 in.)

shears of open-sided construction are preferred, but for shears of greater capacities a closed-frame type has been developed. The arrangement of such a unit is shown in Fig. 34 ; the driving gear and lever system is duplicated on each side of the shear, synchronism of movement being ensured by the provision of a cross-connecting shaft. The levers of the two systems are coupled to common top and bottom blade holders, which are guided in the main frame. The shear is equipped with holding-down gear, stop measuring gear, rack type crop-end pusher, and swinging roller for the disposal of crop ends into a bogie located underneath the delivery table.

Demag 52 in. × 6 in. or 14 in. × 14 in. Electrically Driven Down- and Up-Cutting Hot Bloom and Slab Shears

This shear, which is of the lever type and is very similar to the Kalmag and Schloemann units, operates in conjunction with a 43½ in. × 9 ft. 3 in. reversing slabbing mill serving a semi-continuous plate mill. It is illustrated in Figs. 35 and 36, which are views taken during shop erection, and Figs. 37 and 38. The shear is driven by means of two motors, each of 500 h.p. and 750 r.p.m., through two-speed reduction gear units giving cutting speeds of 3 and 10 strokes per minute. It is capable of cutting slabs up to 52 in. wide × 6 in. thick and blooms up to 14 in. square, and of exerting

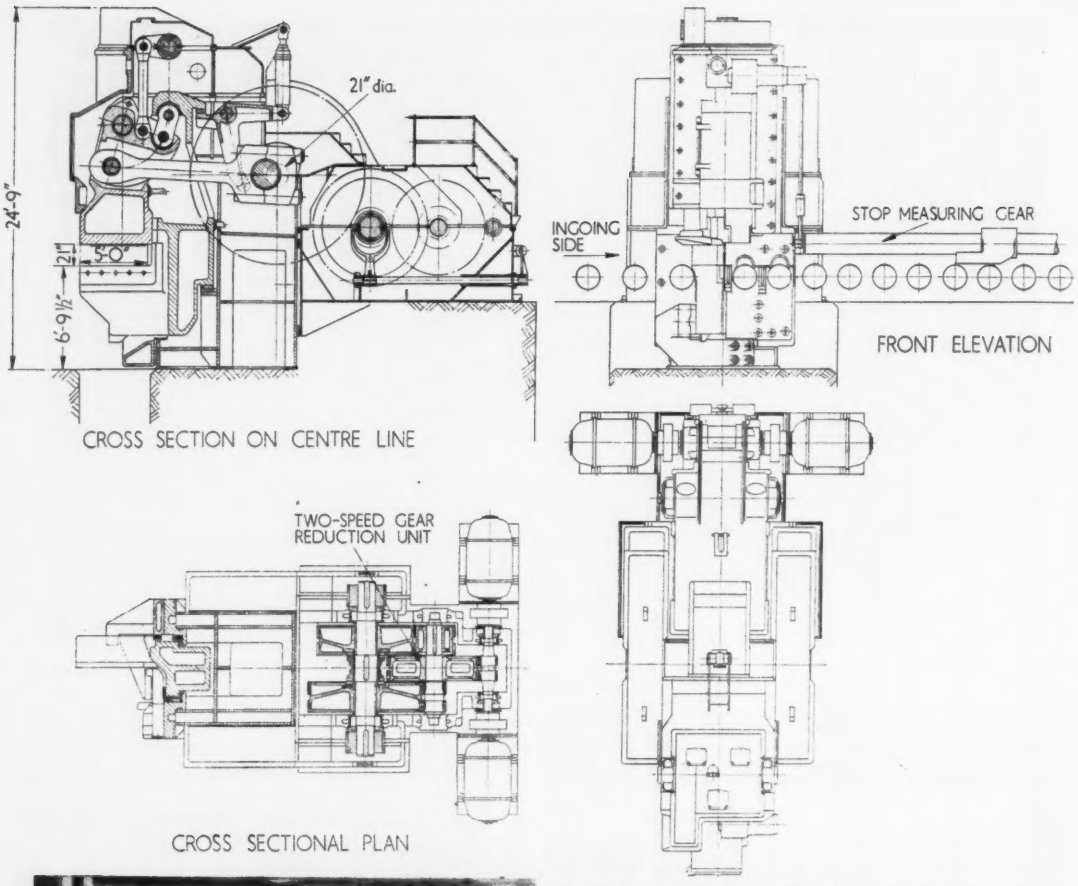


Fig. 39—Arrangement of Sack electrically driven down- and up-cutting hot bloom and slab shear for a blade load of 1500 tons (Scale : 1 in. = 11 ft. 6 in.)

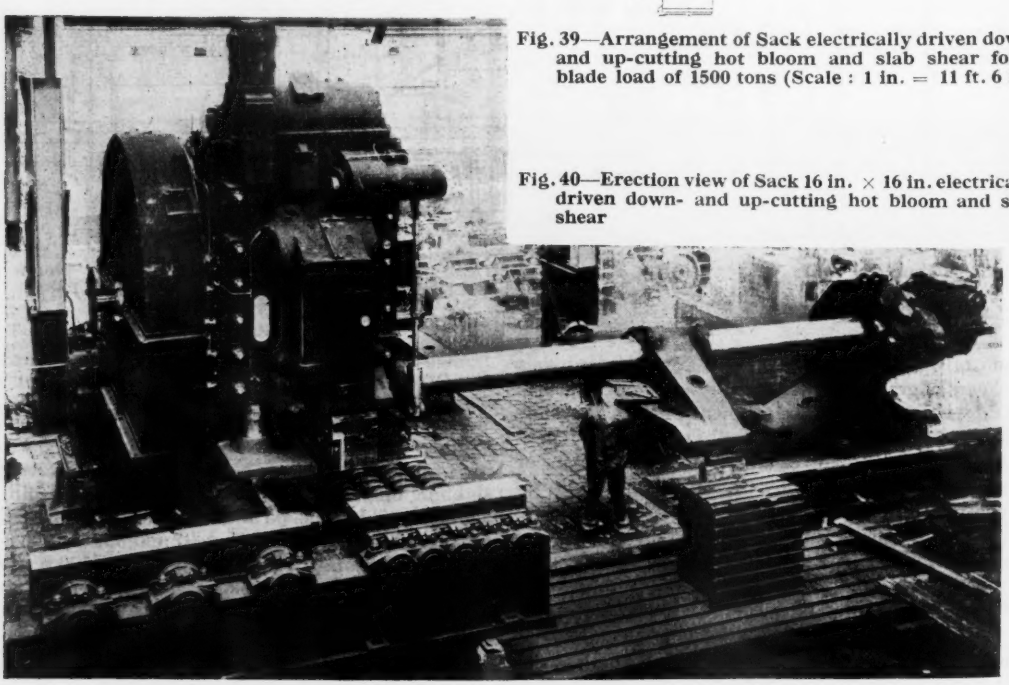
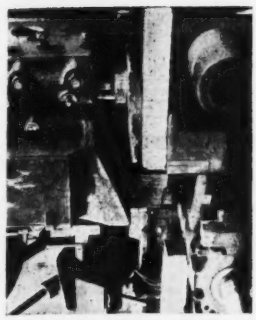
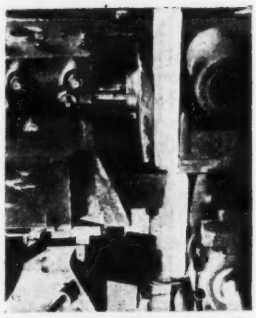
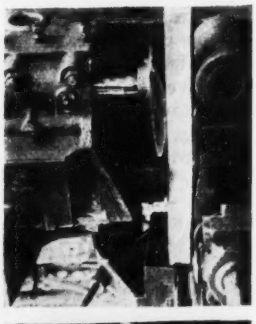
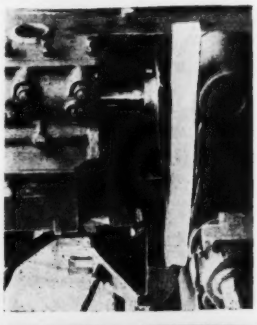


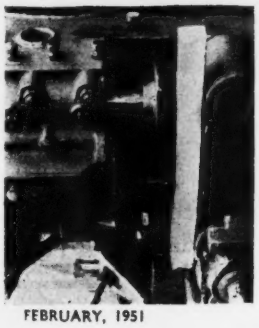
Fig. 40—Erection view of Sack 16 in. × 16 in. electrically driven down- and up-cutting hot bloom and slab shear

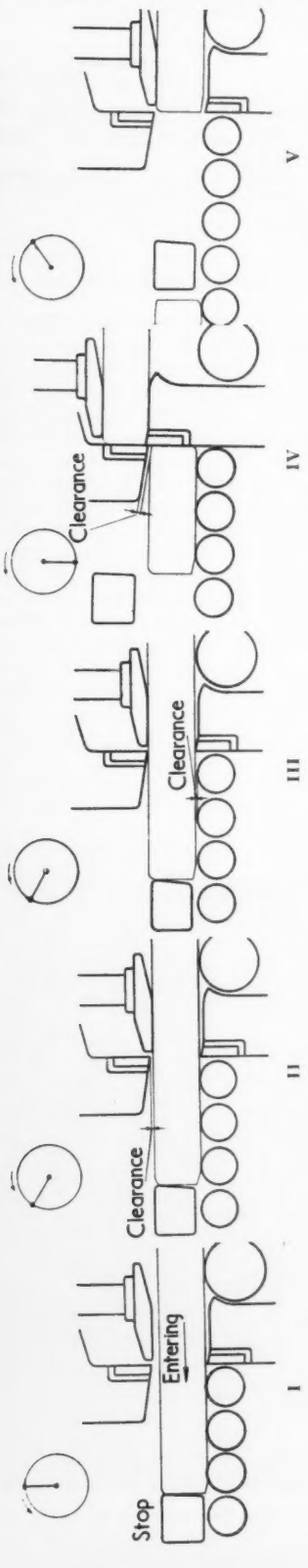












a maximum pressure of 1500 tons on the blades.

Crop-end removal is carried out by means of two push-off devices discharging into bogies arranged alongside the roller table. Electrically operated winches are provided for hauling the filled bogies into an adjacent building for emptying and then returning to the shear.

Sack Electrically Driven Down-and Up-Cutting Hot Bloom and Slab Shear

This shear, of which perhaps a greater number have been built than of any other type, develops its cutting power by means of an ingenious, but simple, lever system. The arrangement of a large shear now under construction is shown in Fig. 39 ; this unit is capable of cutting slabs up to 60 in. wide × 6 in. thick, and of exerting a maximum pressure of 1500 tons on the blades. It is driven by two variable-speed reversible motors through triple-reduction gearing and two-change speed gear. The shop-erection view of a shear of this type, for cutting blooms up to 16 in. square, is shown in Fig. 40.

A point of interest in the Sack shear is the automatic holding-down gear, the operation of which is synchronized with the movement of the blades ; Fig. 41 shows diagrammatically the sequence of operations during the cutting cycle.

Electro-Hydraulic Intensifier

The electro-hydraulic intensifier has not been very widely used, although a number of units have been successfully applied to bloom and slab shears. The two types that have been developed differ essentially in the manner in which movement of the hydraulic ram is effected. In one design this is done by means of a toothed rack attached to the free end of the ram and a pinion which engages with it. This pinion is driven through reduction gearing by a variable-speed

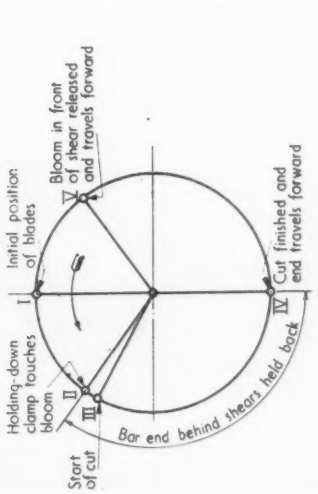


Fig. 41—Sack electrically driven down- and up-cutting hot bloom and slab shear. Diagram showing sequence of operations

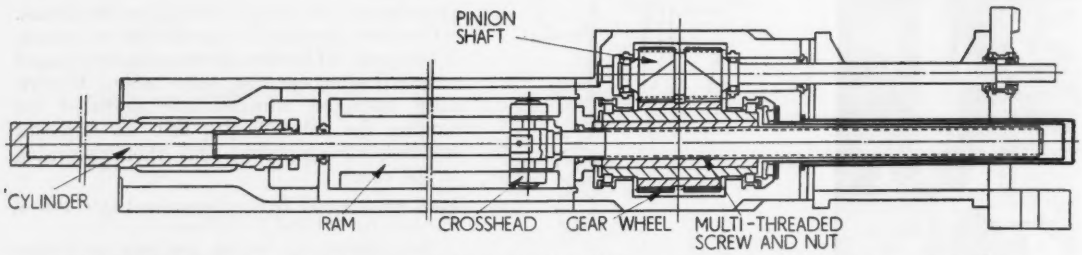


Fig. 42—Diagrammatic arrangement of electro-hydraulic intensifier unit (Scale : 1 in. = 7 ft. 6 in.

reversible motor, usually with Ward-Leonard control, and the stroke of the ram is governed by the operator to suit the section being cut ; limit switches are provided which cut out or reverse the motor at the end positions of the ram.

In the alternative design, the ram is moved by a multi-threaded screw, working in a long nut which is rotated by a variable-speed reversible motor through reduction gearing ; a system of electrical control similar to that fitted to the rack type of unit is usually employed. The arrangement of a typical screw-driven intensifier is shown in Fig. 42 ; Fig. 43 is a shop-erection view of a unit as applied to a 16 in. × 16 in. hot bloom shear. In this case, however, the nut is driven through double-reduction gearing with two-change speeds.

United 12½ in. × 48 in. Electrically Driven Down- and Up-Cutting Hot Slab Shear

This shear, which is typical of the latest American practice in this type of equipment, is being installed to operate in conjunction with the heavy reversing slabbing mill serving a continuous hot-strip mill. The arrangement of the shear proper is illustrated in Fig. 44, which shows that it is of the closed-frame type with underhung crank. It is capable of exerting a maximum blade pressure of 1350 tons, and is driven electrically through a 42·5 : 1 reduction gear unit to give cutting speeds of 9–18 strokes per minute ; in this respect it is considerably faster than most European electrically driven shears. Since the shear is of the down- and up-cutting type, both top apron and bottom bolster are movable ; the driving crank is mounted in bearings in the bolster, and is connected to the apron at the cam portions through two heavy side links. The whole of this assembly, *i.e.*, top apron, bottom bolster, camshaft, and side links, with connecting pieces and holding-down gear, is guided vertically in the main frame of the shear.

The driving power is transmitted from the reduction gear unit to the camshaft by universal spindle ; to initiate the cut, the motors are started up and the camshaft rotates in its bearings in the bottom bolster, thus bringing down the top apron until it meets the piece. Immediately the resistance builds up, the camshaft commences to rotate about the

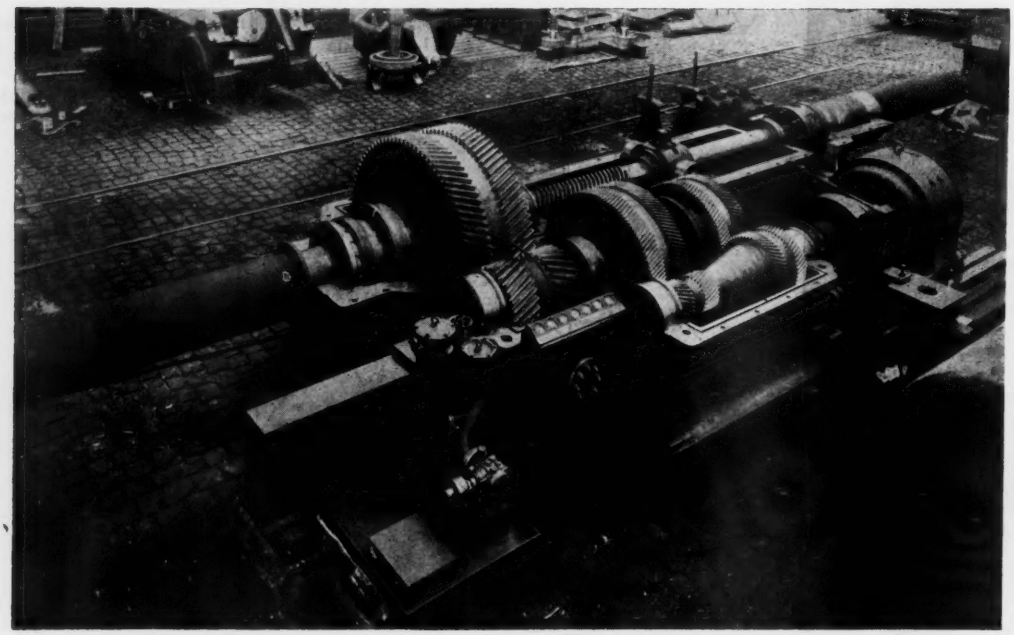


Fig. 43—Erection view of electro-hydraulic intensifier unit for 16 in. × 16 in. hot bloom shear

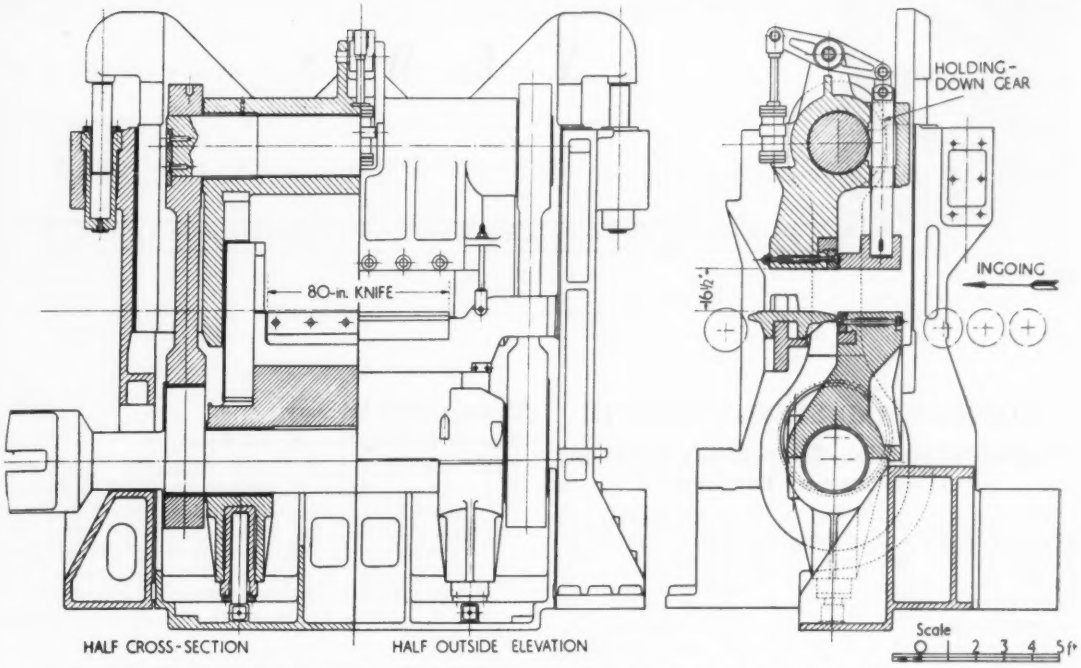


Fig. 44—Arrangement of 12½ in. × 48 in. United electrically driven down- and up-cutting hot slab shear, for a blade load of 1350 tons

cam centres, thus forcing the bottom bolster upwards to complete the cut. Normally the camshaft makes one complete revolution, but in the event of a stall the drive can be reversed to free the piece. A shop erection view of a typical shear of this type is shown in Fig. 45.

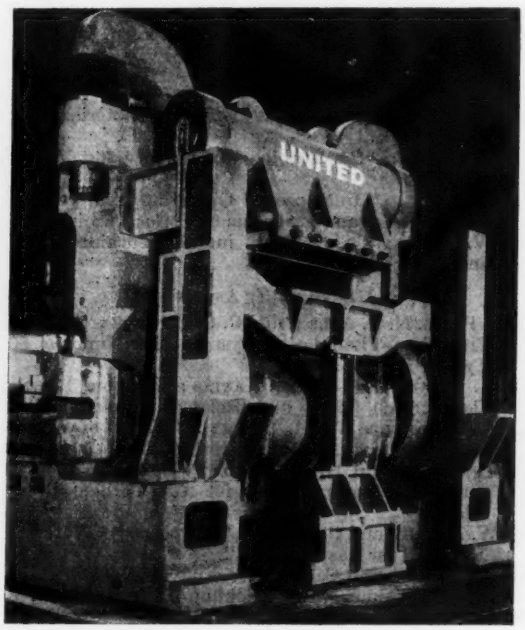


Fig. 45—Erection view of United electrically driven down- and up-cutting hot slab shear from in going side

Acknowledgments

The author wishes to express his thanks to the Directors of Messrs. Colvilles, Ltd., and Associated Companies, for permission to publish this paper; to colleagues for their assistance and helpful criticism; to the Managements of many steelworks for the supply of information relative to shear-blade performance; to the makers of rolling-mill machinery, who have provided many of the illustrations of modern shearing equipment; and to Davy and United Engineering Co., Ltd., for supplying the information contained in Table I.

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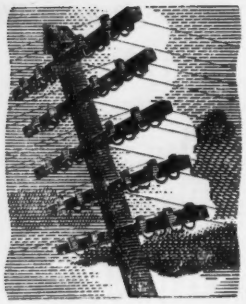
2. W. F. CARTWRIGHT : *Proceedings of the Institution of Mechanical Engineers*, 1938, vol. 139, pp. 249–284.
3. J. PUPPE and G. STAUBER : Walzwerkswesen, vol. 2, pp. 38–42. Berlin, 1934 : Julius Springer.

(Data giving particulars of blades and performance, in connection with Table II, were received too late for publication with this paper. They will be provided by the author when presenting the paper, and will be printed with the discussion in a later issue of the Journal.)



N E W S

ANNOUNCEMENTS AND NEWS OF SCIENCE AND INDUSTRY

THE IRON AND STEEL INSTITUTE

Symposium on High-Temperature Steels and Alloys for Gas Turbines

The Symposium will take place on **Wednesday** and **Thursday, 21st** and **22nd February, 1951,** in the Lecture Theatre of The Institution of Civil Engineers, Great George Street, London, S.W.1. Non-members of The Iron and Steel Institute will be welcome at the meetings and functions and to contribute to the discussions.

The Sessions will begin at 10.0 A.M. and 2.30 P.M. on each day.

Buffet Luncheons will be available from 1.0 to 2.30 P.M. in the South Reading Room of The Institution of Civil Engineers on both days.

A Dinner for those attending the Symposium will be held at the Hyde Park Hotel, Knightsbridge, London, S.W.1. on Wednesday, 21st February, 1951, at 7.0 for 7.30 P.M.

The following is the detailed programme and list of papers.

Detailed Programme

Wednesday, 21st February

Morning Session, 10.0 a.m. to 1.0 p.m.

10.0 A.M.—Opening remarks by the Chairman, Sir Andrew McCance, LL.D., D.Sc., F.R.S., Past-President.

10.5 A.M.—Outline of the purpose of the Symposium by Mr. D. A. Oliver, Chairman of the Organizing Committee.

10.10 A.M.—Introduction. "A Survey of the Development of Creep-Resisting Alloys." By Dr. N. P. Allen.

10.25 A.M.—Discussion on the papers in Group III, "Supplier Aspects." Rapporteur, Dr. H. Sutton (Ministry of Supply).

1.0 P.M.—Buffet Luncheon in the South Reading Room.

Afternoon Session, 2.30 to 5.0 p.m.

2.30 P.M—Discussion on the papers in Group V, "Special Casting Techniques." Rapporteur, Dr. T. A. Taylor (National Gas Turbine Establishment).

3.45 P.M—Discussion on the papers in Group VI, "Welding and Machinability Aspects." Rapporteur, Dr. E. C. Rollason (Murex Welding Processes, Ltd.).

7.0 for 7.30 p.m.—Dinner for Symposium participants at the Hyde Park Hotel, Knightsbridge, London, S.W.1.

Thursday, 22nd February

Morning Session, 10 a.m. to 1.0 p.m.

10.0 A.M.—Discussion on the papers in Group VII, "Special Blade Materials." Rapporteur, Professor G. Wesley Austin (Cambridge University).

11.30 A.M.—Discussion on the papers in Group IV, "Performance Aspects: Scaling and Fatigue at Elevated Temperatures." Rapporteur, Mr. D. G. Sopwith (National Physical Laboratory).

1.0 P.M.—Buffet Luncheon in the South Reading Room.

Afternoon Session, 2.30 to 5.0 p.m.

2.30 P.M.—Joint discussion on the papers in Group II, "User Aspects," and Group VIII, "Research and Future Needs." Rapporteur, Mr. R. G. Voysey (Ministry of Fuel and Power).

List of Papers

I—Introduction

N. P. ALLEN: "A Survey of the Development of Creep-Resisting Alloys."

II—User Aspects

A. T. BOWDEN and W. HRYNISZAK: "Materials and Performance."

J. B. BUCHER: "Gas-Turbine Performance and Materials."

S. L. BRAGG: "Influence of Operating Temperature on the Design and Performance of Gas Turbines."

R. W. BAILEY: "Stresses in Gas-Turbine Discs and Rotors."

III—Supplier Aspects

L. B. PFEIL, N. P. ALLEN, and C. G. CONWAY: "Nickel–Chromium–Titanium Alloys of the Nimonic 80 Type."

D. A. OLIVER and G. T. HARRIS: "Some Proven Gas-Turbine Steels and Related Developments."

G. T. HARRIS and W. H. BAILEY: "Effect of Warm-Working on an Austenitic Steel (*G18B*)."

G. T. HARRIS and H. C. CHILD: "Development of a High-Temperature Alloy for Gas-Turbine Rotor Blades."

H. W. KIRKBY and C. SYKES: "Properties of Materials Intended for Gas Turbines."

H. W. KIRKBY and C. SYKES, "Study of the Properties of a Chromium–Nickel–Niobium Austenitic Steel."

E. W. COLBECK and J. R. RAIT: "Creep-Resisting Ferritic Steels."

H. H. BURTON, J. E. RUSSELL, and D. V. WALKER: "Ferritic Steels for Gas Turbines."

W. E. BARDGETT and G. R. BOLSOVER : "Special Steels for Gas Turbines."

IV—Performance Aspects : Scaling and Fatigue at Elevated Temperatures

A. PREECE : "Scaling of Gas-Turbine Alloys."
C. SYKES and H. T. SHIRLEY : "Scaling of Heat-Resisting Steels : Influence of Combustible Sulphur and Oil-Fuel Ash Constituents."
H. J. TAPSELL : "Fatigue at High Temperatures."
P. H. FRITH : "Fatigue Tests at Elevated Temperatures."
H. E. GRESHAM and B. HALL : "Hot Fatigue Testing."
G. T. HARRIS and M. T. WATKINS : "Variation of Elastic Moduli with Temperature for Various Steels and Pure Metals."

V—Special Casting Techniques

A. E. THORNTON and J. I. MORLEY : "Centrispun High-Alloy-Steel Aero-Engine Components : *Part I*—The Centrispinning Process. *Part II*—Physical and Mechanical Properties of Centrispun Die Castings."
J. TAYLOR and D. H. ARMITAGE : "Centrifugal Steel Castings for Gas Turbines."
H. E. GRESHAM and A. DUNLOP : "Investment-Casting of Nozzle Guide Vanes."
E. R. GADD : "Precision Casting of Turbine Blades."

VI—Welding and Machinability Aspects

H. E. LARDGE : "Welding of Heat-Resistant Alloys in Sheet Form."
E. BISHOP and W. H. BAILEY : Weld-Metal Properties and Welding Characteristics of Two Austenitic Steels Used for Gas-Turbine Rotors."
K. J. B. WOLFE and P. SPEAR : "Machining Austenitic and Ferritic Gas-Turbine Steels."

VII—Special Blade Materials

E. A. G. LIDDIARD and A. H. SULLY : "Chromium-Base Alloys for Gas-Turbine Applications."
J. C. CHASTON and F. C. CHILD : "Some Cobalt-Rich Alloys for High-Temperature Service."
H. J. GOLDSCHMIDT : "Phase Diagrams of the Ternary Systems Fe–Cr–W and Fe–Cr–Mo at Low Temperatures."
R. W. A. BUSWELL, W. R. PITKIN, and I. JENKINS : "Sintered Alloys for High-Temperature Service in Gas-Turbines."
T. G. CARRUTHERS, and A. L. ROBERTS : "Ceramics as Gas-Turbine Blade Materials. A Survey of the Possibilities."
L. ROTHERHAM, W. WATT, J. P. ROBERTS, and F. J. BRADSHAW : "Ceramics for Gas Turbines."
P. GROOTENHUIS and N. P. W. MOORE : "Sweat-Cooling : Review of Present Knowledge and its Application to the Gas Turbine."

VIII—Research and Future Needs

C. A. BRISTOW and H. SUTTON : "Research and Development on High-Temperature Materials."
J. M. ROBERTSON : "Future Needs in Materials for Land and Marine Gas Turbines."

Presentation and Discussion of Papers

The papers will be presented in suitable groups by a rapporteur for each group. The subsequent discussion will be 'open' and those present will be invited to make their contributions without waiting to be called on by name by the Chairman. At the same time, if any participants can notify the Secretary in advance that they will wish to speak on certain groups of papers it will be of assistance in arranging the proceedings.

Contributions to the discussion by correspondence from anyone unable to attend the Symposium will be accepted. They should reach the office of the Institute not later than 5th March, 1951.

Fifth Hatfield Memorial Lecture

The Memorial Lecture, on "Turbine Problems in the Development of the Whittle Engine," will be delivered by Air Commodore Sir Frank Whittle, K.B.E., C.B., M.A., D.Sc., F.R.S., on the evening of **Tuesday, 20th February, 1951,** at 8.30 P.M. in the York Hall, Caxton Hall, Caxton Street, London, S.W.1.

The Chair will be taken by Sir Andrew McCance, LL.D., D.Sc., F.R.S., Past-President.

Special Meeting in Austria, 1951

The Council of The Iron and Steel Institute has accepted an invitation from the Austrian Iron and Steel Institute (Technisch-wissenschaftlicher Verein "Eisenhütte Oesterreich"), President Dr. J. Oberegger, to hold a Special Meeting in Austria from **5th to 19th September, 1951.** The Council of the Institute of Metals, which is holding its Autumn Meeting in Italy from 16th to 26th September, has invited any Members of The Iron and Steel Institute who so wish, to attend the Meeting in Italy, with their Ladies, whether they are Members of the Institute of Metals or not ; the Council of The Iron and Steel Institute has accepted this invitation and has extended a similar invitation to Members of the Institute of Metals and their Ladies to attend the Meeting in Austria. Visits to some non-ferrous works will be included in the programme in Austria and visits to some iron and steel works will form part of the programme in Italy.

The Austrian Reception Committee will consist of the Council of the Eisenhütte Oesterreich. An Executive Committee has been formed and is composed as follows :

CHAIRMAN : Dr. J. Oberegger (Oesterreichische Alpine Montangesellschaft A.G.)

MEMBERS : Dr. Roland Mitsche (Montanistische Hochschule, Leoben) ; Dr. F. Narbeshuber (Oesterreichische Alpine Montangesellschaft A.G.) ; Dr. F. Platzer (Rektor, Montanistische Hochschule, Leoben), Dr. H. Rapatz (Gebrüder Böhler A.G.)

JOINT HON. SECRETARIES : Dr. R. Walzel (Montanistische Hochschule, Leoben) ; Lt.-Col. N. Watson (Oesterreichische Alpine Montangesellschaft A.G.)

A Ladies Committee is also being formed.

The first party will leave London on Wednesday, 5th September, 1951, and arrive at Bad Ischl on the following day ; they will be able to visit either the iron and steelworks at Lintz or the aluminium works at Ramshofen, on 7th September ; on the 8th September they will travel from Bad Ischl to Graz *via* Trieben, visiting the works of Veitscher Magnesit A.G. en route. On Sunday, 9th September, this party will have the day free in Graz. A second party will leave London on Saturday, 8th September, arriving at Graz on the evening of 9th September. Members and Ladies who wish to make their own arrangements for travel to Austria will be able to join the meeting at Bad Ischl or Graz.

Members and Ladies will remain in Graz from the evening of 9th September, until the morning of the 14th. The following items will be included in the programme in and near Graz :

One afternoon for the discussion of technical papers.
Visit to the Montanistische Hochschule at Leoben.
Visit to 'Iron Mountain' at Eisenerz.

Visits to the following works:

Oesterreichische Alpine Montangesellschaft, Donawitz.
Gebrüder Böhler A.G., Kapfenberg.
Felten und Guilleaume A.G., Bruck.
Oesterreichische Alpine Montangesellschaft, Kindberg.
Steyr-Daimler-Push A.G., Graz.
Andritzer Maschinen-Fabrik, Graz.
Elin A.G., Veiz.

A number of social functions and an attractive programme of excursions for the Ladies are being arranged in and near Graz and Leoben.

On 14th September the whole party will travel by bus from Graz to Pörtschach, near Klagenfurt, and will remain there until the morning of 16th September.

Visits to the following works will be included in this section of the programme:

Kärtnerische Eisen- und Stahlwerke, Ferlach.
Guild of Gun Makers, Ferlach.
Magnesitwerk Radenthein, A.G.
Bleihütte, Gailitz.

Ladies' excursions and evening functions will also be included.

Members and Ladies who will be joining the meeting of the Institute of Metals in Italy will leave by train on the afternoon of Saturday, 15th September, for Venice. Members and Ladies not going to Italy will stay at Pörtschach till the morning of 16th September and will be able then either to return home direct to England, arriving on Monday, 17th September, or to travel by bus over the Gross Glockner Pass to Zell-am-See; this latter party will remain at Zell-am-See until the morning of 18th September; there will be a one-day visit to the power station and dams at Kaprun on the 17th. The party will arrive back in London on the evening of Wednesday, 19th September.

Members and Ladies making their own travel arrangements back from Austria will be able to leave the meeting at Pörtschach or Zell-am-See.

A preliminary notice giving a more detailed programme and approximate prices will be issued shortly; an outline programme of the meeting of the Institute of Metals in Italy will be issued to all Members of The Iron and Steel Institute at the same time. Full details and forms of application for the meeting will be circulated to all Members of both Institutes in April or May.

NEWS OF MEMBERS

▶ Dr. J. H. ANDREW, a Vice-President of the Institute, had the title of Emeritus Professor conferred on him by the University of Sheffield, on 10th November, 1950.

▶ Mr. I. M. BIDGOOD has left University College, Cardiff, to take up an appointment as metallurgist with George Kent, Ltd., Resolven, Glamorgan.

▶ Mr. J. S. BROADLEY has been awarded the Ph.D. degree of Glasgow University and has taken up an appointment as a Senior Scientific Officer with the Ministry of Supply.

▶ Mr. G. W. BROWN has resigned his position as metallurgist with Messrs. S. Smith and Sons, Ltd., to take up an appointment as Chief Metallurgist with Messrs. Douglas (Kingswood) Ltd. Bristol.

▶ Mr. E. L. DIAMOND has been awarded the Ph.D. degree of the University of London.

▶ Dr. A. J. GOULD has been appointed Professor at Howard College, University of Natal, Durban, South Africa.

▶ Sir WILLIAM T. GRIFFITHS, Chairman and Managing Director of The Mond Nickel Co., Ltd., has resigned from the Company.

▶ Mr. F. O. JONES has left the A.E.I. Research Laboratory and is now Assistant Lecturer in Metallurgy at University College, Swansea.

▶ Mr. C. MINIFIE has been appointed Chief Technical Engineer to Derbyshire Stone Ltd., Matlock.

▶ Mr. F. MOBEY has resigned his position as Lecturer in Metallurgy at Manchester University to take up an appointment as Lecturer in Metallurgy at the R.A.F. Technical College (Engineering Division), Henlow, Bedfordshire.

▶ Mr. T. A. NIGHTINGALE has received an A.Met. of Sheffield University and has been transferred to Associateship of the Institution of Metallurgists. He has taken up an appointment as Assistant Metallurgist with The Park Gate Iron and Steel Co., Ltd.

▶ Mr. R. T. PARKER has been appointed Director of Research, Aluminium Laboratories, Ltd., Banbury.

▶ Mr. J. B. RENWICK has left the British Iron and Steel Research Association and is now Senior Chemist with Messrs. C.A.V., Ltd.

▶ Mr. J. E. SRAWLEY has left the Research and Development Department of The Mond Nickel Co., Ltd., to take up an appointment as a Scientific Officer with the British Cast Iron Research Association.

▶ Mr. A. J. STOKES has left Wellworthy Piston Rings, Ltd., Lymington.

▶ Mr. M. SWAROOP has resigned his position as Works Manager at the Hind Metal Works, Ltd., Aligarh, India.

▶ Dr. C. SYKES, Member of Council of the Institute, has been appointed Deputy Managing Director of the Brown-Firth Research Laboratories, Sheffield.

▶ Mr. W. D. Walker has left the Metallurgy Department of the University of Witwatersrand, Johannesburg, to join the South African Bureau of Standards, Pretoria.

▶ Mr. J. P. WARNER is now with Sherritt Gordon Mines, Ltd., Ottawa.

▶ Dr. D. R. F. WEST has left the Armament Research Establishment to take up an appointment as Lecturer in the Department of Metallurgy, Imperial College, London.

▶ Mr. D. H. WILKINSON has taken up an appointment with the Bahrein Petroleum Co., Ltd., at Awali.

▶ Mr. R. R. WILLAN has been awarded the B.Eng. degree, with honours in metallurgy, and has entered the Springfields Factory of the Department of Atomic Energy of the Ministry of Supply.

New Year's Honours

▶ Mr. B. E. BLACKLEDGE, Superintendent of the Coke Ovens and Fuel Departments of The Steel Company of Wales Ltd., has received the M.B.E.

▶ Mr. S. K. DAVIES, Chairman and Managing Director of George Elliot and Co, Ltd., Cardiff, has received the C.B.E.

▶ Dr. W. HUME-ROTHERY, Lecturer in Metallurgy at Oxford University, has received the O.B.E.

Obituary

Mr. J. H. FARMER, General Manager of the Central Marine Engine Works of William Gray and Co., Ltd., on 8th November, 1950.

Lt.-Col. Sir J. GREENLY, an Honorary Vice-President of the Institute, on 31st December, 1950.

Mr. S. GUY NEWTON, Joint Managing Director of Brown, Bayley's Steel Works, Ltd., on 22nd December, 1950.

CONTRIBUTORS TO THE JOURNAL

W. Shepherd Owen, M.Eng.—Lecturer in the Department of Metallurgy, Liverpool University. Mr. Owen was educated at Alsop School and at the University

of Liverpool. He graduated in 1940 with first-class honours in metallurgy and was awarded a Kitchener Memorial Scholarship. In that year he entered the laboratories of the Napier–English Electric Co. organization and was subsequently in charge of the laboratories, and later of the metallurgical and X-ray laboratories of the English Electric Co. at Rugby. He was awarded the degree of M.Eng. in 1942.

Mr. Owen returned to the Department of Metallurgy of the University of Liverpool in 1946, and now holds a Lectureship specializing in metallography and X-ray metallography.

S. G. Street, B.Eng.—A member of the Metallurgy Department, Liverpool University. Mr. Street was educated at Wirral Grammar School, and at Liverpool University. He graduated with honours in metallurgy in 1948 and was awarded a Joseph and Lucy Chadwick Post-Graduate Studentship.

Mr. Street has carried out research work on graphite and carbide phases in commercial and high purity 'cast iron type' alloys.

P. R. Beeley, B.Met., A.I.M.—Steel-Foundry Metallurgist at Messrs. Hadfields, Ltd., Sheffield. Mr. Beeley was born in 1923, and was educated at King Edward VII School, Sheffield. After early industrial experience in the Laboratories and Foundry of Messrs. Edgar Allen and Co., Ltd., Sheffield, he entered Sheffield University to read Metallurgy, graduating B.Met. in 1943. Mr. Beeley subsequently joined the research and development staff of Messrs. David Brown and Sons (Hudd.) Ltd., being engaged on problems connected with the production of carbon and alloy steel castings in the Penistone and Salford Foundries of the Group.

In 1946 he relinquished this post and returned to Sheffield University to undertake steel castings research on behalf of the British Iron and Steel Research Association; this work continued until the end of 1949, when he took up his present appointment.

IRON AND STEEL ENGINEERS GROUP

The **Fourteenth Meeting** of the Group will be held in London on **Thursday, 5th April, 1951.** The programme will include the presentation and discussion of a paper "*Electric Drives for Reversing Hot Mills*," by P. E. Peck (B.T.-H. Co., Ltd.) and a paper "*Hot Bloom and Slab Shears*," by J. A. Kilby (Colvilles Ltd).

The meeting will probably commence at 10.0 A.M. but further details will be announced later.

Meeting of Junior Engineers

A Meeting of Junior Engineers was held at Ashorne Hill, Leamington Spa, on Wednesday and Thursday, 22nd and 23rd November, 1950. Members of the Engineers Group of The Iron and Steel Institute and Members of the Staff of Member Firms of the British Iron and Steel Research Association were eligible to take part in the Meeting, provided they were under the age of 35. Approximately 90 people were present. Several members of the Engineering Committee of the Institute came to the Meeting. Mr. C. H. T. Williams, Chairman of the Iron and Steel Engineers Group, was in the Chair.

The proceedings opened on the Wednesday afternoon with the discussion of a paper on "*The Impact of Modern Maintenance Practice and Labour Conditions in the Engineering Workshop in the Steel Industry*," by Mr. G. C. Oram, Appleby-Frodingham Steel Co.

Mr. Oram gave a brief outline of the influence on the attitudes of higher management in the steel industry to the engineering workshop, resulting from the introduction of 'Preventive Maintenance' and from the effects of full employment. He discussed production control and workshop organization and advanced arguments for 'centralization' and 'decentralization.'

The discussion was opened by Mr. H. J. Strong (Dorman, Long and Co., Ltd.) who commented from the mechanical engineer's point of view and Mr. M. Y. Harvey (Morgan Crucible Co., Ltd.; lately of Colvilles Ltd.) who spoke from the standpoint of the electrical engineer. Mr. Strong emphasized that centralization required a more specialized staff that would be difficult to enlist from the present works engineering staffs; he also felt that urgent repairs would be delayed if they had to pass through a highly organized central workshop. He thought that the ideal arrangement would be one central workshop to handle major repairs with small shops decentralized to handle urgent smaller jobs. He welcomed the arrangements for special training of apprentices outlined by Mr. Oram.

Mr. Harvey suggested that centralization was difficult to justify for electrical repair work and that small shops were more flexible. He wanted to know whether maintenance costs were increased by the presence of the large central organization, what was the proportion of non-productive staff employed, and how were incentives provided? He thought that the organization described by Mr. Oram was too cumbersome, and that, in view of the rough treatment received by equipment in the works, the improved quality of workshop output claimed by the centralized workshop was hardly justified.

Mr. Oram in reply said that at Appleby-Frodingham all the specialist staff had been found within the firm; small emergency workshops were needed at strategic points in the works, but these should be provided sparingly. Repair costs were being decreased in spite of the higher overheads and staff was gradually being reduced. Incentives had not been found necessary so far, but they might be needed later. Equipment was not found to be out of action any longer with centralized than with decentralized workshops. Experience was showing that well-finished equipment was treated with more care in the works. Comprehensive records were being kept which it was hoped would, in time, show the overall benefits of the centralized arrangement.

During the lively open discussion the following points among others were raised: the procedure for alloting priorities for urgent work in a centralized shop; the installation of gear-cutting and hardening equipment; the saving of time and labour in assembly work; the need for the electrical repair shop to be self-contained except for large mechanical jobs; the organization of the centralized workshop virtually as a 'jobbing shop' and co-operation with other works departments to enable longer runs when making certain spare parts; costing and job-card procedure and the cost and organization of transport between the central workshop and the various departments of the works.

In the evening Mr. W. F. Cartwright delivered a lecture on "*The Steel Company of Wales Ltd.: Developments at Port Talbot.*" He gave a short historical review of the development of the old works at Margam and Port Talbot and a detailed description of the alterations being made at Margam and of the new steelworks and hot and cold strip mills being built at the Abbey Works. The description covered civil, mechanical, and electrical engineering aspects of the project, and was of outstanding interest to everyone present.

The morning of Thursday, 23rd November, was devoted to a discussion on the "*Training of Works Engineers.*" Mr. C. Grad, (British Thomson-Houston Co., Ltd.) presented a paper on "*The Training Arrangements for Engineers in the Electrical Industry*," which described the training of engineers at the B.T.-H. Co., Ltd.

Mr. Grad emphasized the need for the training of professional engineers, technicians, and craftsmen and described the B.T.-H. apprentice scheme that has been in operation for 50 years; details were given of (*a*) the Graduate and Engineering Student Apprenticeship Courses for training professional engineers; (*b*) the Engineering Student and Drawing Office Apprenticeship Courses for training electrical technicians; and (*c*) the various trade courses for craftsmen. He then discussed the responsibility for training, liaison with local technical colleges, and co-ordination of training arrangements. Reference was also made to apprentice hostels, apprentices' associations, and other welfare arrangements, including parents' days, etc. Statistics were given of the annual intake of apprentices and of the number trained, and reasons were given why manufacturing organizations trained more men than they could themselves absorb.

The discussion was opened by Mr. W. C. Churchward (Stewarts and Lloyds, Ltd.) and Mr. R. G. Dixon (Thos. Firth and John Brown, Ltd.) Mr. Churchward outlined the training scheme for engineers in operation at a medium-sized steelworks and asked whether this scheme was adequate or whether it would be better for the steel industry to import engineers trained in other industries; he also asked whether in the B.T.-H. scheme trainees could be transferred 'sideways' as well as 'upwards.'

Mr. Dixon suggested that apprentices should have a short period of general instruction before starting their technical training so as to give them some insight into the works; their training in the production shops should be in the order of the production line and they should not be put for training under craftsmen who have no labourer with them. Periodical lectures by senior staff in general works engineering questions—*e.g.*, water supply, electric generation and distribution, etc.—are advantageous. Apprentices should be encouraged to write and deliver short papers; when the apprenticeship is finished, trainees should, where possible, be sent for a short period to another firm or even into another industry. Mr. Dixon also felt that a better system for note-taking at lectures in technical colleges should be devised and that more co-operation between technical institutions is needed to avoid the necessity of candidates taking two almost identical examinations in the same subject for different societies.

Mr. Grad said in reply that they had found that promotion of craftsmen *via* the drawing office to 'black-coated' employment was not always desirable. B.T.-H. had craftsmen's scholarships by which selected craftsmen of 24 years of age could go abroad to work with foreign firms and widen their craft experience. He agreed that the training scheme described by Mr. Churchward was adequate and felt that each industry and each large firm should have its own scheme. At B.T.-H. the preliminary selection training period served the purpose of giving apprentices an insight into the various branches of the works, but care had to be taken not to bias their choice. The apprentice supervisor, whether whole-time or part-time, must see that apprentices are not used as labourers and that they are not kept back when due for transfer from one section to another in the works. Engineering lectures are given to some trainees at B.T.-H.; also training in administration is needed and can probably best be given in post-apprenticeship courses.

An open discussion followed. Some of the points discussed were: the composition and methods of appointment of selection committees for entrants to the training schemes; the impact of National Service on training schemes; the employment given to technical personnel during their period in the Forces and their re-absorption afterwards; the length of time spent by apprentices in each department; the exchange of engineers between firms, both at home and abroad; the present-day standard of craftsmen; comparison of the training facilities available for mechanical engineers with those available for electrical engineers; the value of the apprentice hostel as a social institution; the use of psychological testing techniques for selection of apprentices for training; and the function of the technical institutions and the principles governing National Certificate Schemes.

The Meeting ended at mid-day on Thursday, 23rd November. It was evident from the wide range of subjects covered in the discussions that great interest has been aroused among those who attended.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION

Deputy Director

MR. W. C. F. HESSENBERG, M.A., F.I.M., has been appointed deputy director of B.I.S.R.A. Mr. Hessenberg has been head of the Association's Mechanical Working Division since March, 1947, and retains this position.

British Rusting Standards Accepted in U.S.A.

In December 1949 the B.I.S.R.A. Corrosion Laboratory issued a series of photographs at natural size depicting different grades of breakdown by rusting of painted steel surfaces. Reprints of these photographs were made freely available in the hope that comparisons in this important field would become more uniform. It is now announced that the standards have been accepted for use by the American Waterworks Association in their exposure tests. This will very greatly facilitate comparison of results of tests carried out here and in America.

NEWS OF SCIENCE AND INDUSTRY

Mond Nickel Fellowships

The Mond Nickel Fellowships Committee has pleasure in announcing the following awards for 1950:

Mr. D. ALEXANDER (University of Otago, New Zealand) to study industrial technique and the application of research to metallurgical control, in Great Britain, with special reference to tinning, plating, enamelling, and other surface-finishing processes.

Mr. F. R. H. ALLON (John I. Thornycroft and Co., Ltd.,) programme not yet decided.

Mr. K. W. J. BOWEN (Cambridge University) to study factors affecting the selection of materials for the construction of chemical and petroleum plant in the U.S.A. and Canada, with particular reference to the influence of research in this field.

Mr. M. G. GEMMILL (United Steel Companies Ltd.) to study in Britain, U.S.A., and Canada the manufacture, testing, and application of steels for high-temperature service.

Mr. W. B. HALL (Nchanga Consolidated Copper Mines Ltd., N. Rhodesia) to study American and Canadian plant practice in the hydro-metallurgy and electro-winning of base metals, with special reference to copper and its associate metals, and to make a general study of mechanization and plant management in ore-dressing and leaching plants.

The Mond Nickel Fellowships Committee will, at a later date, invite applications for awards for 1951. Full particulars of the Fellowships can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1.

Institution of Chemical Engineers

The Graduates' and Students' Section of the Institution of Chemical Engineers is holding a Convention on "*Chemical Engineering : Opportunities in Specific Industries,*" at Nutford House, London, from Wednesday to Sunday, 11th–15th April, 1951. Enquiries should be addressed to the Convention Secretary at the Institution of Chemical Engineers, 56 Victoria Street, London, S.W.1.

Canadian International Trade Fair

The fourth Canadian International Trade Fair, sponsored by the Canadian Government and dedicated to Canada's International Trade Fair, will be held in Toronto from 28th May to 8th June, 1951. Particulars may be obtained from the Canadian Government Exhibition Commission, Canada House, Trafalgar Square, London, S.W.1.

Coke-Oven and By-Product Recovery Plant

The National Coal Board (Durham Division) have placed an order with The Woodall-Duckham Vertical Retort and Oven Construction Company (1920), Ltd., for the design and erection of a comprehensive Coke-Oven and By-Product Recovery Plant to be built at Fishburn Colliery, Co. Durham. The plant is designed to carbonize 1000 tons of coal per day. It comprises 50 W-D Becker Combination Underjet-type Coke Ovens with appropriate oven machinery, coal blending, storage, and service bunkers ; coke handling, screening, and storage bunkers, and full by-product recovery equipment for the production of crude tar, sulphate of ammonia, and crude benzole. The contract includes the civil engineering work associated with the plant, water-cooling and recirculation services, and the construction of extensive railway sidings. Arrangements are being made by the National Coal Board for the disposal of the coke-oven gas to the Northern Gas Board.

New 42-in. Slabbing Mill at Shotton

Extension of works capacity at the Hawarden Bridge Steelworks of John Summers and Sons, Ltd., at Shotton, near Chester, was originally planned in 1939, and has been proceeding steadily ever since. Much new plant has been installed since 1944, including extensions to slab-furnace capacity, an annealing plant, new soaking pits, 80-in. wide, four-high, reversing cold strip and skin pass mills, a fourth stand to the 56-in. wide tandem cold mill, an 80-in. coil slitting and trimming line, and a 74-in. wide rotary shear line.

Recently, a further addition has been the installation of a new 42 in. × 8 ft. 0 in. reversing slabbing mill, with a lift of 61 in., designed to handle ultimately a tonnage virtually double that of the present Shotton plant. The slabbing mill previously in service at Shotton could produce slabs of 40-in. maximum width : the new slabbing mill can produce slabs of 55-in. maximum width, and 7-in. thickness, and this enables the hot mill to operate now as a fully continuous line. This Davy-United mill, which was supplied complete with a slab shear of 900 tons blade load, is the new primary unit of the Shotton wide-strip mill. It has been designed to accept a maximum ingot size of 15 tons, and, handling this size, the mill should easily reach the proposed weekly output of 20,000 tons. At present the mill is handling only 8-ton ingots, but soon it will be rolling 12½-ton ingots.

The mill has closed top-roll housings which have been so constructed that roll changing may be done by the simultaneous axial withdrawal of both rolls. The housing screws are of special 0·5% forged carbon steel, and are 16 in. in diameter ; screwdown gear is supplied with twin-motor electric drive, from two 150-h.p. motors which give a screwing speed of 250 in./min. Top-roll balance is provided from two hydraulic cylinders carried in the housing tops, which have 12-in. diameter Fencolized cast-iron rams, capable of giving a hydraulic working pressure of 700–750 lb./sq. in.

The mill rolls are cooled by sprays from a water box which is carried between the two balance beams for the top roll. Long slabs travelling down the continuous roller table reach the open-sided, up-cutting hydraulic slab shear, which is capable of cutting slabs of 55-in. width and 5-in. thickness, or of equivalent section up to a maximum thickness of 8 in. The maximum blade load and stroke are 900 tons and 12 in. respectively, and a continuous cutting rate of three cuts per minute is possible.

The manipulating equipment of the mill was required to conform to a particular and novel design originally drawn up by Summers' engineering staff. The manipulator is essentially of the electrically operated universal side-guard type, and all actuating mechanism is positioned on the main-drive side of the mill, leaving the other side free for roll-changing operations. The tilting gear is a unique feature of this equipment, and is of the four-finger type. Operation of the mill is carried out by a three-man crew, housed in a modernly designed control cabin placed above and athwart the mill approach table.

Birlec, Ltd.

Birlec, Ltd., announce the appointment of Mr. S. G. KING, A.M.I.E.E., as their London Manager, with offices at 35 Park Street, London, W.1. Mr. King has had 20 years' experience of electric furnace work, particularly in connection with the development and sale of arc and high-frequency melting equipment.

Electric Resistance Furnace Co., Ltd.

Mr. J. A. MONKS, a Director of the Electric Furnace Co., Ltd., and the Electric Resistance Furnace Co., Ltd. has been appointed Joint Managing Director of the latter company.

Sanderson Bros. and Newbould

The Company have announced the following new appointments : Mr. H. T. WORDSWORTH, Commercial Director, becomes General Manager ; Mr. J. R. A. BULL becomes Sales Manager ; and Mr. E. O. STUBBINGS becomes London Director.

Samuel Osborn and Co., Ltd.

The Clyde Steel Works of Samuel Osborn and Co., Ltd., Sheffield, announce the appointment of three local Directors, Mr. F. MAY, Mr. L. HARPIN, and Mr. John H. OSBORN.

Titanic Steel Co. Ltd., have appointed Mr. E. PASLEY, Chief Metallurgist, and Mr. H. DAKIN, Forge Manager, to be Directors of the Company.

The Osborn Foundry and Engineering Co., Ltd., Sheffield, announce the appointment of Mr. W. T. HILL, at present Commercial Manager, as a Director of the Company.

British Timken, Ltd.

The death is announced of Mr. M. B. U. Dewar, Chairman of British Timken, Ltd., on 21st December, 1950.

Industrial Publications

▶ A paper on the use of fuel oil in furnaces, by M. Roddan, which was presented at the Conference on Modern Applications of Liquid Fuels at Birmingham in

1948, has now been issued as a reprint by Shell-Mex and B.P., Ltd.

The account is comprehensive, and includes illustrated descriptions of a number of types of furnace, showing the versatility of oil-firing.

▶ The Commercial Division of the British Thermostat Co., Ltd., has published a brochure describing the construction and operation of the new series of electric proportioning valves and controls which have been added to their 'Teddington' range. The units provide proportioning control of motors, dampers, valves, etc., in relation to temperature, pressure, and humidity changes.

▶ A booklet to meet the demand for concise information, on tinplate from buyers and users, has been published by the Tin Research Institute, under the title "The Tinplate Handbook."

In addition to information on processing, application, and testing of various types of tinplate, the trade terms used by British and American tinplate industries are defined, and a glossary of English–French–German–Spanish technical trade terms is given.

▶ A collection of papers on "Productivity Measurement in British Industry" is published by the Anglo-American Council on Productivity.

Articles describe the application in many industries, including a steelworks, of the computing methods that are used to obtain statistical information. This information is afterwards tabulated and arranged to show fluctuations in efficiency and the effect of changes. The performances of a group of factories, a single factory, a department, and of operatives are examined.

DIARY

1st Feb.—EBBW VALE METALLURGICAL SOCIETY (Joint Meeting with The Iron and Steel Institute)—"*The Properties Required for Various Forming Operations*," by G. Murray—Lecture Room, Messrs. Richard Thomas and Baldwins, Ltd., Ebbw Vale, 7.15 P.M.

1st Feb.—LIVERPOOL METALLURGICAL SOCIETY—"*Electrodeposition for Engineering Purposes*," by A. W. Hothersall—Electricity Service Centre, Whitechapel, Liverpool, 7.0 P.M.

2nd Feb.—MANCHESTER ASSOCIATION OF ENGINEERS—"*Planning for Production Efficiency*," by Sir Claude Gibb (Annual Lecture)—The Engineers' Club, 17 Albert Square, Manchester, 6.45 P.M.

2nd Feb.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—Annual Dinner—Wulfrun Hall, Wolverhampton.

2nd Feb.—INSTITUTION OF MECHANICAL ENGINEERS—"*Industrial Design and Its Relation to Machine Design*," by H. G. Conway—The Institution, 5.30 P.M.

5th Feb.—INSTITUTE OF BRITISH FOUNDRYMEN (Sheffield Branch)—"*Oxygen as an Aid to Production of Carbon Foundry Steel in the Arc Furnace*," by A. C. Brearley—Royal Victoria Station Hotel, Sheffield, 7.30 P.M.

5th Feb.—SOCIETY OF ENGINEERS—Presidential Address by P. S. Ham, followed by Annual Dinner—Geological Society, Burlington House, W., 5.0 P.M.

7th Feb.—NORTH WALES METALLURGICAL SOCIETY—"*Problems Encountered in the Fabrication of Mild Steel Sheets*." by A. Rowlands—County Primary School, Shotton, Chester, 7.15 P.M.

14th Feb.—MANCHESTER METALLURGICAL SOCIETY (Joint Meeting with The Iron and Steel Institute)—"*Instrumentation of Steelmaking Furnaces: Some of the Problems*," by R. Toye—Engineers' Club, Albert Square, Manchester, 6.30 P.M.

15th Feb.—STAFFORDSHIRE IRON AND STEEL INSTITUTE—"*Nodular Iron*," by H. Morrogh—Station Hotel, Dudley, 7.30 P.M.

16th Feb.—ROYAL INSTITUTE OF CHEMISTRY (London and S.E. Counties Section)—"*Corrosion Processes and Their Prevention*," by W. H. Vernon—Brighton Technical College, 7.0 P.M.

16th Feb.—MANCHESTER ASSOCIATION OF ENGINEERS—"*Modern Methods of Painting Machinery and Workshops*," by S. A. Wood—Engineers' Club, 17 Albert Square, Manchester, 6.45 P.M.

16th Feb.—WEST OF SCOTLAND IRON AND STEEL INSTITUTE—"*Induction Heating for Forging*," by K. G. Quicke—39 Elmbank Crescent, Glasgow, 6.45 P.M.

17th Feb.—SWANSEA AND DISTRICT METALLURGICAL SOCIETY—"*Cast Iron in Relation to Ingot Moulds*," by W. H. Glaisher—Central Library, Swansea, 6.30 P.M.

19th Feb.—SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—"*Some Aspects of Modern Steelmaking*," by A. Robinson—Royal Victoria Hotel, Sheffield, 6.15 P.M.

20th Feb.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Organisation and Use of a Metallurgical Laboratory in a Small Steel Works*," by G. Robinson—Grand Hotel, Sheffield, 7.0 P.M.

20th Feb.—FIFTH HATFIELD MEMORIAL LECTURE—"*Turbine Problems in the Development of the Whittle Engine*," by Air Commodore Sir Frank Whittle—York Hall, Caxton Hall, Westminster, 8.30 P.M.

21st–22nd Feb.—THE IRON AND STEEL INSTITUTE—Symposium on High-Temperature Steels and Alloys for Gas Turbines—Institution of Civil Engineers, Gt. George St., S.W.1, 10.0 A.M. and 2.30 P.M.

23rd Feb.—INSTITUTION OF MECHANICAL ENGINEERS—"*Fatigue Tests*," by C. E. Phillips, R. B. Heywood, and A. J. Fenner—The Institution, 5.30 P.M.

27th Feb.—SHEFFIELD METALLURGICAL ASSOCIATION—"*Organic Reagents for Metallurgical Analysis*," by J. H. Osborne—Grand Hotel, Sheffield, 7.0 P.M.

28th Feb.—INSTITUTE OF BRITISH FOUNDRYMEN—"*Valve Guide Castings*," by R. Dulche—Waldorf Hotel, Aldwych, W.C.2, 7.30 P.M.

TRANSLATION SERVICE

(The previous announcement was made in the January, 1951, issue of the *Journal*, p. 76).

TRANSLATION AVAILABLE

No. 416 (German). O. RÜDIGER: "Progress in the Non-Destructive Testing of Materials by Supersonics." (*Stahl und Eisen*, 1950, vol. 70, June 22, pp. 561–565; discussion, p. 565).

TRANSLATION IN COURSE OF PREPARATION

(German). G. NIEBCH and A. POMP: "Influence of Various Heat-Treatments and Alloy Additions on the Cold-Working of Steel." (*Stahl und Eisen*, 1950, vol. 70, Dec. 7, pp. 1166–1173; discussion, pp. 1173–1174).

CHARGES FOR COPIES OF TRANSLATIONS—The charge for the above translations is £1 for the first copy and 10*s.* for each additional copy of the same translation. Requests should be accompanied by a remittance. These translations are not available on loan from the Joint Library.

TRANSLATIONS PREPARED AT MEMBERS' REQUEST—Members requiring translations of foreign papers are invited to communicate with the Secretary, who will ascertain whether they can be prepared for inclusion in the Series.

ABSTRACTS OF CURRENT LITERATURE *and* BOOK NOTICES

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MINERAL RESOURCES

Titanium and Iron Minerals from Black Sands in Bauxite. W. A. Calhoun. (United States Bureau of Mines, 1950, Report of Investigations 4621). In the treatment of Arkansas bauxite, black sand containing titanium and iron minerals is being discarded. This report describes laboratory tests involving screening, tabling, and magnetic separation by which an ilmenite concentrate and an iron oxide concentrate could be recovered from the sand.—R. A. R.

The Metallurgical Industry in Peru. (Metalurgia y Electricidad, 1950, vol. 14, Apr., p. 42). [In Spanish]. This is a brief note on the development work of the Peruvian Corporacion del Santa.

The main iron ore deposits are found in the pampas of Marcona in the Department of Ica. The Corporation is studying the possibilities of exploiting these deposits in conjunction with the hydroelectric station at the port of Chimbote.

Sixteen million tons of high-grade ore have been estimated, with a reserve of one hundred million tons. The ore will be quarried and it is hoped to achieve an output of 30,000 tons/annum of electric pig iron at a low cost.—R. S.

Mining and Metallurgical Industry of Cuba. F. Mota. (Metalurgia y Electricidad, 1950, vol. 14, May, pp. 26–29). [In Spanish]. The author describes briefly the physical geography and the geology of Cuba. The development of Cuban mineral resources is reviewed from a historical viewpoint. A table of mineral concessions and the number of hectares worked is given. Iron, copper, chromium, manganese, and gold ores are worked. The main iron ore mines are Daiquirí and Mayarí which possess more than a quarter of the total reserves of iron ore of Latin America. In manganese, Cuba is second to Brazil as a producer. Almost all fuel has to be imported from the U.S.A. There is, however, a large metallurgical plant in Havana and a tube works and iron foundry. In Cristo, in Oriente province, the largest plant in the world for the concentration of manganese ores was recently installed.—R. S.

ORES—MINING AND TREATMENT

Beneficiation of Northern Iron Ores. F. X. Tartaron. (American Iron and Steel Institute: Association of Iron and Steel Engineers Yearly Proceedings, 1949, pp. 783–788). The future of the iron ore situation in the U.S.A. is briefly reviewed and methods of concentrating low-grade ores are surveyed. When the ground ore is below 100 mesh it is too fine to sinter. In Minnesota a test plant is pelletizing a wet concentrate containing 50% or more of minus 325 mesh by rolling it into balls in a rotating cylinder; the balls are afterwards baked in a shaft furnace. Jigging, flotation, the Humphrey spiral, magnetic separation, and gravity separation in heavy media are briefly explained. Within about 20 years beneficiation will have to be increased so as to produce 50 million tons of high-grade concentrate per annum; this means treating 500,000 tons of crude ore every 24 hr.—R. A. R.

Proposed Process for Treatment of Low-Grade Titaniferous Ores. R. T. MacMillan, J. I. Dinnin, and J. E. Conley. (United States Bureau of Mines, 1950, Report of Investigations 4638). An essentially chemical technique has been developed on a small scale for the efficient utilization of certain American titaniferous iron ores. Three main steps are involved: (1) Sintering the ore at 1050° C. with carbon and soda ash to reduce the iron to metal powder, retaining the titania in the slag; (2) separating the powdered iron from the slag, after wet grinding, by magnetic or gravity methods; and (3) sulphuric acid decomposition of the titania fraction to produce pigment and certain by-products.—R. A. R.

Micro-Radiography Applied to the Study of Iron Ores and Sinters. E. Cohen. (Metallurgia, 1950, vol. 41, Feb., pp. 227–233). The technique for the microradiography of ores is described and several examples of microradiographs at 70 diameters are shown; beside each is a photomicrograph of the same field at the same magnification. The interpretation of the pictures obtained by the two processes is explained and the advantages of the former for studying ores are pointed out.—R. A. R.

FUEL—PREPARATION, PROPERTIES, AND USES

Flame Velocity in Stationary Flames. A. Schack. (Stahl und Eisen, 1950, vol. 70, June 8, pp. 519–520). The work of E. Bartholomé is reviewed. Previous results based on measurements on flames burning at the mouth of wide tubes are shown to be some 20% too low, because in non-turbulent flow through such tubes the gas velocity at the axis is twice that at the walls. Accurate and reproducible results are obtained when premixed gases are passed through jets. The most important results are as follows: With 'warm' flames of temperature below 2200° C., in which dissociation of CO_2 and hydrogen play no part, preheating increases flame propagation speed in proportion to the increase in flame temperature. The preheating of a methane–oxygen mixture to 1000° C. (?) increases flame velocity threefold. The flame velocity is the same whether temperature is increased by preheating or by adding oxygen to an air supply. This shows

that the chemical combustion velocity has no essential part but that the propagation speed is determined by thermal conduction. When burning hydrocarbon vapours of different octane number or with different concentrations of lead tetraethyl, the octane number or knock resistance has no influence on flame speed. This is in line with the facts quoted above. Combustion starts just before the fringe of the flame is reached, *i.e.*, when the gases attain a very high temperature, well above the ignition point. Reaction velocity is therefore very small in the neighbourhood of the ignition point. If the flame temperature rises above 2200° C. its velocity increases markedly. This is attributed to hydrogen atoms producing thermal dissociation. These diffuse back into the oncoming gas and give up their great latent energy. There are thus two types of flame propagation; thermal conductivity with 'warm' flames and diffusion of hydrogen atoms with 'radical' flames. Between 2000 and 2400° C. there is a transformation between the two mechanisms. It is confirmed that maximum flame velocity is not attained, as would be expected, at complete combustion but when there is a deficiency of air. This is attributed to the greater concentration of hydrogen atoms. Measurements have been made on combustion velocities. A theoretical mixture of methane and air takes 10^{-9} sec. to increase 1° C. in temperature at 2000° C., 10^{-8} sec. at 1700° C., and 10^{-7} sec. at 1450° C. If these values are calculated for a 500° C. rise, then reaction periods of about 1 sec. are required at a temperature of 900° C. These results are of importance in connection with the evaluation of flames in combustion chambers and with the back-firing of furnaces. A simplified formula has been developed for the calculation of flame velocity which yields results of great accuracy; it can be used to predict velocities of mixtures not yet measured.—J. P.

Flameless Gas Firing with Turbo Burners. J. Göbel. (Bányászati és Kohászati Lapok, 1950, vol. 5, July, pp. 425–426). [In Hungarian]. The advantages of flameless combustion with turbo gas burners are described with special reference to the metallurgical industry. This method has a high efficiency and since there is no excess air much less of the charge is oxidized.—E. G.

The Influence of the Flow on the Combustion Process. D. Diószeghy. (Bányászati és Kohászati Lapok, 1950, vol. 5, May, pp. 318–328). [In Hungarian]. The influence of the flow on the combustion process is investigated and it is pointed out that the type and speed of flow have a considerable influence on the chemical reactions in the various types of furnace and gasification plant. The investigation is based on data in the literature and on gasification experiments carried out by the author on a block of coal 30 × 30 × 30 cm. In these experiments it was observed that the CO_2 formed was reduced to CO along the path of laminar flow, but the latter combined again with free oxygen further along where the flow was turbulent.—E. G.

Flame Speed as Affected by Preheating of Gaseous Fuels. J. D. Keller. (Industrial Heating, 1950, vol. 17, May, pp. 780–786). The dependence of combustion velocity on preheat is discussed in the light of conflicting experimental evidence. Results of various investigators are analysed and theoretical aspects considered. The author points out that in the earlier tests insufficient attention was paid to aerodynamic conditions and that flow was in many cases non-turbulent. It is concluded from the information available that for rich gases the flame speed varies as the square of the absolute temperature; for a city gas containing 36% of methane and 11% of hydrogen it varies approximately as $T^{1.8}$; and for dry CO in air, approximately as $T^{1.6}$.—J. A. L.

Radiant Gas Burners. J. D. Keller. (American Gas Association: Industrial Heating, 1949, vol. 16, Nov., pp. 1966–1976; Dec., pp. 2154–2162, 2234; 1950, vol. 17, Jan., pp. 52, 56, 172; Feb., pp. 234–238, 366–370; Mar., pp. 434–444). Forty-three porous-diaphragm burners and 18 perforated-block burners of the following types have been tested: (1) The Moran porous-diaphragm burner, (2) the Selas cup-type burner, (3) the Humphrey Radiant-fire. The turn-down ratio over which the Moran burner remained lighted in the open was at least 26 if based on a maximum pressure of 12 oz./sq. ft., or at least 17 if based on 8 oz./sq. in. max. Tests on the Selas and the Radiant-fire burners of the porous-diaphragm type are discussed. The development of perforated block burners with various inspirator and elbow arrangements, their dimensions and design, the probable limit of radiating efficiency, and the apparent cracking of gas are also dealt with.—R. A. R.

Blast Furnace Gas Boosts Steam Plant Output. P. J. Berg. (Industrial Heating, 1950, vol. 7, June, pp. 1010–1016). The installation of a power and steam generating plant by the Dravo Corporation of Pittsburgh is described. The new plant includes equipment to burn 2,500,000 cu. ft./day of 110 B.Th.U./cu. ft. blast-furnace gas which had previously been wasted to atmosphere. By this means steam generating capacity was increased by 200,000 lb. of steam at 165 lb./sq. in. and power output by 7500 kW. without increasing fuel costs.—J. A. L.

Recuperators for Small Industrial Furnaces. W. Trinks. (Industrial Heating, 1950, vol. 17, July, pp. 1182–1186). The Thermobloc recuperator designed to produce a high flame temperature from lean gases is described. The recuperator contains two sets of tube banks at right angles and in contact with each other. Flue gases pass through one set while air, or air plus gas, passes through the other. A high rate of heat transfer, 18 B.Th.U./sq. ft./hr./degree Fahrenheit is claimed. J. A. L.

Analyses of Iowa Coals. (United States Bureau of Mines, 1949, Technical Paper No. 706).

The Design of Dense Media Coal Washers, with a Description of the Ridley-Scholes System. F. F. Ridley. (Colliery Guardian, 1950, vol. 181, Sept. 21, pp. 241–247; Sept. 28, pp. 275–279). The design of coal washers is described, with particular reference to those using suspensions of finely divided solids in water as the separating medium. The required stability of suspensions depends on the design of the washer. The relative merits of shallow (1–1·5 m.) and deep (5–6 m.) baths are discussed; in either case present practice allows capacities of 30–50 tons/hr./m. of feed width. Handling mechanism in baths is to be avoided, where abrasive media are used. Velocities of greater than 2 m./sec. are recommended to avoid choking. Drainage and spraying screens of the high-speed type, well loaded to give efficient operation are favoured. Design of the regeneration system is important where costly materials (*e.g.*, magnetite, barytes, etc.) are used. Purfication and thickening by settling tanks or cyclones are mentioned, and automatic density control recommended. The Ridley-Scholes system, described in detail, uses a suspension of 1·5 sp. gr., which is about half magnetite. The shallow bath is 1·3 m. deep, tapering uniformly to zero, and its floor is covered by a rubber conveying belt. The passage of the floats is assisted by paddles operating in the same direction as the flow of medium. Magnetite recovery is entirely by screening and sedimentation.—T. E. D.

Evaluating Washery Performance. H. F. Yancey and M. R. Geer. (International Conference on Coal Preparation, Paris, 1950: Colliery Guardian, 1950, vol. 181, Sept 14, pp. 221–226). The Tromp distribution curve, developed from the Hancock Efficiency Chart, is the best way of summarizing the data of a washing operation, and shows clearly the sharpness of the separation effected. Families of curves are obtained for different mesh sizes of the raw coal. The efficiency formula usually employed is that of Fraser and Yancey. A tabular comparison of a number of coal-washing operations is given.—T. E. D.

Losses of Large Coal during Grading. P. Synek. (Bańsky Obzor, 1950, vol. 4, Jan., pp. 10–16; Feb., pp. 17–21; Mar., pp. 41–44). [In Czech]. The factors influencing the proportions of different sizes in the unscreened coal from four Czech mines are examined and a method for predetermining the quantities of individual grades before screening is given. E. G.

A Study of Pressure Relationships in Coke Ovens. J. Hamilton and T. Kennaway. (Year-Book of the Coke Oven Managers' Association, 1950, pp. 152–178). An extensive study has been made on a coking plant to determine the factors affecting the maintenance of a slightly positive pressure in the chambers. The general conclusions were: (1) It is possible to maintain the ovens under pressure at all times except when charging or discharging; (2) at normal gas-collecting-main pressures (*e.g.*, 4·0 mm. W.G.) it is necessary to peg the valve of the ovens in order to achieve the conditions required by (1); (3) it is possible to maintain the ovens under pressure at all times without pegging, provided that the gas-collecting-main pressure is high enough—

a pressure of 7·0–7·5 mm. W.G. is required; (4) under the conditions in (3), smokeless charging would be impossible and there would be grave risk of damaging the oven structure; (5) the plant should be operated at a safe pressure of 5·0 mm. W.G. and a pegging schedule adopted on as simple a scale as possible; and (6) the ascension pipes are of ample capacity to perform their designed function whatever the pressure in the mains.—R. A. R.

Development of a Possible Method of Estimating the Excess Air Used in Combustion. H. J. Victory. (Year-Book of the Coke Oven Managers' Association, 1950, pp. 125–151). In this mathematical paper an attempt is made to link the gross calorific value (Hg) of gaseous fuel with the composition of actual waste gases in such a manner as to permit estimation of excess air from a knowledge of Hg and the waste-gas composition, using data from numerous analyses of coke-oven gas and blast-furnace waste-gas analyses from South Wales plants.—R. A. R.

The Recovery of Benzole at Gas Works and at Coke Ovens. W. H. Hoffert and G. Claxton. (Fourth World Power Conference, London, 1950: Gas World, 1950, vol. 132, July 22, pp. 100–107). The literature on the recovery of benzole at gas works and coke ovens is reviewed with special reference to developments since 1945. There are 36 references.

R. A. R.

Production of Water Gas in Coke Ovens. C. O. Otto and Company. (Coke and Gas, 1950, vol. 12, Mar., pp. 99–107). A description is given of the design and operating results of tall horizontal ovens at Kiel gasworks producing water-gas by steaming coke in the oven chambers. The ovens are 13¾ in. wide, 13 ft. 1½ in. high, taking a charge of 9·2 metric tons of raw coal. The results indicate that this plant fulfils the demands of the works for (*a*) flexibility in gas production and calorific value, (*b*) the production of a small-sized coke of good quality, (*c*) the gas-making capacity on the limited ground area available, and (*d*) safe and simple operation.

R. A. R.

New Crystal Ammonium Sulphate Plant at A.I.S. Kembla Works. (B.H.P. Review, 1950, vol. 27, Mar., pp. 20–22). A brief description is given of the plant and process for the manufacture of ammonium sulphate which have recently been put in operation at the Kembla Works of Australian Iron and Steel Ltd. The plant is designed to use the Wilputte Coke Ovens Corp. 'crystal' sulphate process by which the crystals produced are large and uniform in size and do not cake during storage.—R. A. R.

Metallurgical Coke (Preparation—Properties—Utilization). J. P. Graham, G. E. Hall, and G. W. Lee. (Fourth World Power Conference, London, 1950, Section B3, Paper No. 1). The paper surveys the present position in relation to the preparation and properties of metallurgical coke with special reference to its use in the blast-furnace. It is now impossible to meet the demands of the iron and steel industry from the reserves of the best coking coals alone; it therefore becomes increasingly necessary to conserve these coals by using coals of lower rank and by greater attention to blending processes.

R. A. R.

A New Method for Thermal Control of Coking Processes Increasing the Output of Coke-Oven Plants. Z. V. Ryska. (Fourth World Power Conference, London, 1950, Section B3, Paper No. 3: Hutnické Listy, 1950, vol. 5, Mar., pp. 94–97). The advantages of determining and controlling the temperature of the coke in coke-oven operation are pointed out and an apparatus for doing this is described. The essential unit is an electronic valve sensitive to infra-red rays. This is connected to an amplifying circuit, a recording instrument, and a fuel-gas valve controller. The electronic recorder is mounted on the coke guide car so that it scans the wall of hot coke passing in front of it when an oven is pushed. It is claimed that this temperature measurement and automatic control lead to an increase of 3–7% in production.—R. A. R.

On the Improvement of the Quality of Coke in Poland. B. Roga. (Fourth World Power Conference, London, 1950, Section B3, Paper No. 4). The author discusses the importance of those methods of testing coking coals which are intended to indicate their behaviour at high temperature, and describes in particular a Polish test for determining the agglutinating value. He considers methods of improving the quality of the coke and the economics of the process.—R. A. R.

REFRACTORY MATERIALS

Evaluation of Silicaquartzite by Transformation Annealing. F. Harders and H. Stützel. (Stahl und Eisen, 1950, vol. 70, Apr. 27, pp. 376–378). The suitability of quartzite sand for silica brick manufacture may be assessed by the readiness with which the quartz transforms on heating to cristobalite and tridymite. The density of a range of sands of German origin is depicted graphically as a function of time and temperature of firing. The resulting curves for good sands conform to a general pattern.—J. P.

Chemical Changes in Basic Brick during Service. T. F. Berry, W. C. Allen, and R. B. Snow. (Journal of the American Ceramic Society, 1950, vol. 33, Apr. 1, pp. 121–132). The characteristic structure, chemical composition, and mineralogical constitution of the different zones found in chrome-magnesite brick after service are discussed. Silicate contamination probably results from the absorption of droplets of premelt slag that reach the open-hearth roof. The analyses of the chrome crystals separated from the various zones indicate that FeO is found as an essential constituent only in the very hot face of the altered brick. Selective solution of the $MgO.Al_2O_3$ portion of the chrome crystals in the silicate matrix is demonstrated by means of chemical analyses and phase-equilibrium data. The lack of growth of the chrome crystals and the tremendous growth of the periclase crystals immediately behind the hot face are described; this may have an important bearing on the peeling of the brick.

Refractory Practice in Acid Electric Steel Melting. R. H. Jacoby and M. Petty. (American Foundryman, 1950, vol. 17, Apr., pp. 117–121). Refractory practice at the Key Company's foundry, St. Louis, is described and illustrated. It includes the lining of the shell and roof of a 1½-ton acid electric furnace, ladle lining and drying, stopper-rod assemblies, and the storage of refractories.—R. A. R.

The Use of Tar Mortar in the Open-Hearth Furnace. R. Frerich. (Stahl und Eisen, 1950, vol. 70, Feb. 16, pp. 153–154). Some particulars are given of the application of a tar mortar for filling the joints between silica bricks in open-hearth furnace roofs. The mortar is supplied dry and requires mixing with a little steelworks tar. The outside of the roof should be inspected daily, and the warmed mortar is easily poured into any gaps in the joints. As the tar is burnt away the mortar sets into a solid porous mass which has sufficient elasticity to take up movements in the roof due to temperature changes. The roof life is prolonged by the use of the mortar.—R. A. R.

New Gun Relines Cupola in One Hour. V. E. Hillman. (Iron Age, 1950, vol. 165, May 4, pp. 94–95). A wet refractory mix is shot from a high velocity gun; it is this velocity that rams the refractories, and any thickness up to 10 in. can be applied. A mix of 40% coarse ganister, 40% fine ganister or fine silica sand, and 20% pulverized clay is used. The moisture content can be very closely controlled and relining is rapid.—A. M. F.

The Handling and Storage of Refractories. G. H. Todd. (American Iron and Steel Institute, May, 1950, Preprint). The economies which can be effected in the handling and storage of refractory bricks by stocking on trestles or 'pallets' and using fork front-lift trucks are discussed, and loading, unloading, and stacking operations are described and illustrated.—R. A. R.

Checker Brick Design, Construction and Use. J. J. Seaver. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 94–98). The author discusses the fundamental design and characteristics of good checker bricks, and briefly reviews causes of failure. The design of blast-furnace stoves and open-hearth regenerators is examined and alternative methods are suggested for insulating stove shells and improving open-hearth furnace design.—M. D. J. B.

Performance of High Magnesia Ramming Mixes. R. Smith. (Journal of Metals, 1950, vol. 188, May, p. 754). A brief description is given of two trials comparing the performance of open-hearth furnace bottoms made by ramming or burning in the normal magnesite mixture with those made by ramming in a high-magnesia mixture. The first trial, comparing a furnace with hearth banks of the rammed-in new material with a similar furnace with a burnt-in magnesite hearth, indicates the high-magnesia mixture to be superior. The

second trial, however, which compares a hearth of rammed-in high-magnesia material, with a top layer of burnt-in magnesite, with a similar hearth of rammed-in magnesite, shows the high-magnesia mixture to give inferior results. Further trials are in progress.—G. F.

Sillimanite Roof Refractories in Basic Electric Furnaces. R. E. Wolfensperger. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference Proceedings, Dec., 1949, vol. 7, pp. 197–205). Four brands of sillimanite-type refractory brick have been tested by building in four panels close to the electrode circle in the roof of a 7-ton basic-lined arc furnace making high-alloy steels. The trial roof failed after 166 heats because two panels became too weak to sustain the load. Experience indicates that any high-alumina refractory not having a coarse matrix of mullite crystals as its chief bonding agent will not give results equivalent to those obtained with a sillimanite-type refractory. R. A. R.

Bottom and Pouring Refractories. L. L. Wells, jun. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference Proceedings, Dec., 1949, vol. 7, pp. 206–211). Experience with electric furnace refractories, and ladle bricks, sleeves, and nozzles at the works of the Carnegie-Illinois Steel Corporation is discussed. There appear to be two ways of trying to obtain a hearth of maximum durability; one is to obtain the maximum magnesia content per cubic foot of refractory by ramming in place nearly pure, chemically bonded, periclase grains; the second is to use high-temperature-fired fairly pure magnesite bricks. Pairs of ingots were poured from ladles with two nozzles so as to compare the effect of fireclay and mullite nozzles on the occurrence of inclusions. The nozzle material alone had little influence on the cleanliness of the steel. Zirconia nozzles were neither eroded nor deformed but cracked radially into four segments.—R. A. R.

Production of Sea-Water Magnesite. O. M. Wicken. (American Institute of Mining and Metallurgical Engineers, Electric Furnace Steel Conference Proceedings, Dec., 1949, vol. 7, pp. 212–217). The methods of producing magnesite from sea water are reviewed.—R. A. R.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Dehumidification of Air for Dry Blast. J. Everetts, jun. (American Society of Mechanical Engineers: Industrial Heating, 1950, vol. 17, Aug., pp. 1370–1378). The problem of the removal of moisture from blast-furnace blast is discussed. In particular four general methods of dehumidification are mentioned: Mechanical refrigeration; absorption refrigeration; solid sorbents; and liquid sorbents.—J. A. L.

Determination of the Density of Air by Nomograms. V. S. Dulin. (Bányászati és Kohászati Lapok, 1950, vol. 5, Aug., pp. 451–452). [In Hungarian]. Graphs are presented to facilitate calculating the density and relative humidity of air under various conditions of pressure and humidity.—E. G.

The Dependence of Coke Requirements in the Blast-Furnace on Blast Temperature. E. Krebs. (Stahl und Eisen, 1950, vol. 70, Apr. 27, pp. 358–360). The heat available from the burning of coke has been calculated and used to evaluate the coke requirements at various temperatures. The usual assumption that a fixed rise in blast temperature causes a fixed decrease in coke requirements is shown to be erroneous, the decrease becoming progressively less as blast temperature rises. The calculated effects are in general agreement with, though somewhat lower than, those found in practice by Joseph in America. The influence of working conditions requires examination.—J. P.

Use of Adirondack Sinter in Blast Furnaces. E. H. Riddle. (Journal of Metals, 1950, vol. 188, Apr., pp. 641–645). A description is given of a blast-furnace trial made to determine the effect of a high percentage of Adirondack Benson sinter in the burden in addition to the Aliquippa sinter normally used. The Benson sinter, made from blast-furnace flue dust and magnetite concentrate, contains 0·95% titania, but has an appreciably higher iron content (64%) and lower silica content (5·4%) than the Canby and Newberry ores which it replaced. The results show that iron quality can be maintained when using 50% Benson sinter in addition to 20% Aliquippa sinter, and that iron production is increased, flue-dust loss decreased, and slag volume lowered. A higher blast temperature can be employed, but close control of the sinter size is necessary.—G. F.

Conditions of Outstanding Blast-Furnace Operation. K. Neustaetter. (Journal of Metals, 1950, vol. 188, Apr., pp. 651–655). Various cases of outstandingly good blast-furnace performance which have been reported in the past are compared, and conditions which are favourable to good performance, such as low slag volume, good structure of ore and coke, and high top pressure, are discussed. It is shown that one favourable condition alone is not enough to cause record production, and in order to achieve best results it is necessary to have a number of favourable factors combined with the absence of unfavourable factors. On the other hand, one unfavourable factor is sufficient to cause poor results.—G. F.

Lessons from Hanging Blast Furnaces. L. M. Fulton. (Journal of Metals, 1950, vol. 188, Mar., pp. 476E–480). The author presents data concerning the behaviour of a blast-furnace which frequently encountered hanging after it was provided with a revolving top and higher blast temperature. The hanging is of two distinct types, termed 'clean' and 'sticky'; with the former, and more prevalent, stock descent virtually ceases, whilst with the latter, stock descent is very slow and proceeds in slips. Hanging is attributed to the semi-rigid diaphragm of the fluid zone coming to rest on top of the bosh, owing either to lack of preheating time or to the amount of lime in the charge. The influence of the distribution of the charge and order of charging on its occurrence are discussed from the theoretical standpoint. It is shown that 'clean' hanging can usually be cured by charging extra coke, whilst 'sticky' hanging is treated by charging excess lime and then extra coke to correct the resulting 'clean' hanging. The addition of extra coke, however, causes the silicon content to increase, and measures for correcting this are discussed. The simplest method is to inject steam into the blast, which reduces the temperature of the superheat zone without appreciably reducing the total heat available, and this practice is now regularly used in cases of hanging. It is emphasized, however, that this method is made necessary because the furnace design is unsuitable for the raw materials used, and it is suggested that hanging would be prevented by lowering the bosh and increasing the preheating space.—G. F.

Instrumental Evaluation of Blast-Furnace Operational Data during the Production of Foundry Iron. E. Feil. (Stahl und Eisen, 1950, vol. 70, June 22, pp. 541–543). The value of instruments for controlling and ensuring optimum working conditions of the blast-furnace is stressed. It is shown that increasing blast temperature leads to reduced top-gas temperature which, in turn, is associated with high CO_2 contents in the blast-furnace gases, and high CO_2 contents signify increased efficiency in the use of coke and thus reduced coke additions. The use of gas temperatures to indicate correct charging sequence and conditions in the gas mains is illustrated.—J. P.

Cooling of Blast Furnaces. E. Blanc. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Aug., pp. 561–567). European and American practice is discussed. For the hearth wall and bosh many European plants use spray-cooling whilst in America cooling pipes or blocks are employed. For the stack, three types of cooling block are available: (1) Closed—useful for bosh, but difficult to install and maintain in the stack; (2) open—not completely filled with water; and (3) closed, with demountable front face—this overcomes the disadvantages of the other two. Coke consumption due to cooling losses is placed between 150 and 220 lb./ton of iron made.—A. G.

Pig-Casting Machine Practice at Woodward. H. A. Byrns. (Journal of Metals, 1950, vol. 188, Mar., pp. 474–475). The pig-casting machine and the casting practice at the Woodward Iron Co. (Alabama) are described. The machine is depended upon to handle the entire output of the three blast-furnaces and has been fitted with emergency water, electricity, and compressed-air supplies in order to avoid delay in cases of failure of the main plant supplies. Close control of the mould coating, consisting of 50% lime and 50% powdered coal, is maintained and special mention made of the covered hot-metal ladles which reduce skull to a minimum and handle at least 200,000 gross tons of iron before relining.—G. F.

Pig Machine Practice at Hanna. A. J. Macdonald. (Journal of Metals, 1950, vol 188, Mar., pp. 476–476A). The three

pig-casting machines and the casting practice at the Hanna Furnace Corp. (Buffalo) are described, a special feature being the depressed track and pouring stand for treating high-sulphur iron. The importance of controlling the preparation and application of the mould coating, consisting of 75% burnt dolomite and 25% powdered coal, is emphasized. A trial of carbon moulds shows that very good results may be expected, but they are difficult to adapt to existing machines. G. F.

Blowing Out Carbon-Hearth Furnaces. G. D. Sells, H. P. Saxer, W. R. Zehner, and C. P. Johnson. (Journal of Metals, 1950, vol. 188, Apr., pp. 646–647; May, pp. 751–753). The four authors describe in detail the methods employed in blowing out carbon-hearth blast-furnaces at their respective works, Pittsburgh Steel Co., Jones and Laughlin Steel Corp., Bethlehem Steel Co., and Interlake Iron Corp. In each case it is emphasized that water must be used sparingly in blowing out this type of furnace.—G. F.

Experiments on the Charging of a Blast-Furnace with Classified Calcareous Ore. J. Leflaive and J. Lemonnier. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Mar., pp. 158–166). Full details are given of an experimental run lasting eight months at Denain on the charging of a blast-furnace with calcareous ore classified by size. The charge was based on ores from Joudreville (Lorraine) and from La Ferrière-aux-Etangs and Chazé-Henry (Normandy); the various size gradings of the ores were charged into the furnace in separate layers. Previously the furnace had operated on run-of-mine ore and sintered blast-furnace dust plus other iron-bearing materials, and the merits and demerits of the introduction of ore crushing and of the charging of size-graded ores (including fines) in comparison with the earlier practice are discussed from the technical and economic points of view. A. E. C.

Guaranteeing the Present Position of Ironmaking in Vizcaya. P. Berroya. (Dyna, 1950, vol. 25, May, pp. 175–191). [In Spanish]. In view of the deterioration in quality and quantity of the rubio ores in the Bilbao mining zone, it is becoming difficult to make Bessemer steels having a sufficiently wide field of application without modifying the present methods of ore treatment. This district must adopt its metallurgical methods to the present qualities of ore if it is to maintain its pre-eminent position in Spanish metallurgy. A greater proportion of carbonates must be charged in blast-furnaces. These carbonates contain 50–59% of iron with 0·40–0·50% of sulphur and are very powdery, requiring sintering. A detailed examination is made of the Domnarfvet practice with magnetite and rich manganese ores, based on data by M. Tigerschiöld, and of the Republic Steel Corporation practice with high top pressure.

The main disadvantages of the Bilbao carbonates for use in the blast-furnace are their powdery nature and their high sulphur content.

Sintering of these carbonates has permitted larger quantities to be charged into the blast-furnaces of Altos Hornos de Vizcaya, and has reduced coke consumption. The lower phosphorus content compared with the rubio ores, lowers the phosphorus in the burden. In view of Swedish and North American practice, the following possible methods of treatment for Bilbao carbonates are discussed in detail: (*a*) Use of the crude ore; (*b*) roasting as is the present practice; (*c*) sintering, with or without prior roasting, and with or without the mixture of the necessary flux; and (*d*) roasting sufficiently for subsequent concentration and final sintering of the mixture with the flux.—R. S.

Hungarian Research Work on Improved Utilization of Bauxite. L. Gillemot. (Aluminium, [Budapest] 1950, vol. 2, Mar., pp. 25–32). [In Hungarian]. The processing of bauxite high in iron will be economical only if it is utilized to produce both iron and 'alum earth,' and Hungarian research work has shown that this can be done. The bauxite is roasted and then a magnetic separation process is applied, as a result of which high-iron and low-iron fractions are obtained. The former can be directly utilized as iron ore, whilst alum earth is produced from the latter by the Bayer process. Drying can be dispensed with, since the ore is roasted prior to magnetic separation. The high-iron fraction has a reduced content of slag-forming components and is suitable for producing high-grade grey iron, and steel for transformer sheets and welding rods. Improved methods are being developed for obtaining alum earth from the low-iron fraction remaining after the magnetic separation.—E. G.

PRODUCTION OF STEEL

Discussion of the Use of Small Converters in the Bessemer Process. E. Lanzendörfer. (Neue Giesserei, 1950, vol. 37, Feb. 23, pp. 65–72: Metallurgia Italiana, 1950, vol. 42, Aug.–Sept., pp. 312–320). **Industrial Experience in the Production of Bessemer Steel in a Small Converter.** E. Lanzendörfer. (Stahl und Eisen, 1950, vol. 70, May 11, pp. 409–416). The many variations of the Bessemer process are described and the relative cost of material when using different charges is discussed. It is shown that the silicon content necessary to heat up the charge may be determined by fracture tests. Sketches are given of the design of 1½ to 3-ton converters. The reactions taking place in the converter are described together with methods of following them by observation of the size of the flame, and of the sparks emitted. A patented process (as used in the Mülheim-Meidirch steelworks) is described; in this the oxidation loss is reduced to 4% by re-using the slag. The causes of converter explosions, which need not be due to overblown charges, are explained. Work in England on the effect of temperature on the combustion of silicon and carbon, and of silicon and carbon content on the temperature rise is considered.—O. H. G.

Blowing a Small Converter with Oxygen and Steam. H. Kosmider and P. E. Hardt. (Stahl und Eisen, 1950, vol. 70, Apr. 13, pp. 303–320). Blast-furnace metal (3·7% C, 0·3% S, 1·0% Mn, 2·2% P, 0·04% S, 0·008% N_2) was blown in a 2-ton converter with mixtures of oxygen and steam or air. The experimental arrangements, which included preheating of the oxygen and provision for taking, during the blow, samples of metal and exit gases and for measuring the temperature of the metal and the temperature and humidity of the exit gases, are fully described. To each heat of steel were added aluminium and manganese and a 1·8-ton rimming ingot was cast therefrom. This was rolled to sheet on which to conduct measurements of notched-bar impact and tensile strengths, yield point, and extension. The specimens for the impact test were aged according to the D.V.M. specification. When blowing with 92% oxygen and steam in the ratio of 1:1 to 1:2·5, refining times were shortened as compared with normal techniques, and it was possible to prepare steels with nitrogen contents of 0·003–0·004%, phosphorus contents being in the range 0·01–0·05%. The impact strength of the aged specimens varied from 8 to 12 kg./sq. cm. depending on the base (lime, soda, or lime and soda) used for dephosphorizing. It was confirmed that the desirable physical properties of a rimming steel depend not only on low nitrogen and phosphorus, but also on a low oxygen content. As the ratio of 92% oxygen to steam was raised, or as the purity of the oxygen was lowered, the nitrogen content of the steel increased. This effect was explicable on the grounds that the nitrogen content of the steel was a function of the nitrogen partial pressure in the exit gases. When blowing with oxygen-enriched air it was impossible to produce nitrogen contents below 0·01%. It was established that when blowing with oxygen-enriched air, the amount of scrap which could be added during a blow was greater than corresponded to the heat available as a result of the low proportion of diluent nitrogen; *e.g.*, when blowing with pure oxygen, 50% of scrap could be melted. The dolomite-lined converter bottom suffered rapid deterioration during blowing with oxygen–steam mixtures, the attack on the dolomite being accelerated by the steel tubes used as gas inlets. A converter bottom of tar-dolomite with copper-lined inlets proved to have a much longer life.—J. P.

Refining Basic-Bessemer Steel with Superheated Steam and Oxygen. W. vor dem Esche. (Stahl und Eisen, 1950, vol. 70, Apr. 13, pp. 322–326). Present trends in improving the quality of basic-Bessemer steel are in the direction of reducing phosphorus and nitrogen contents. Tests on a 40-ton converter have shown that this can be effectively carried out by mixing superheated steam at the rate of 7 tons/hr. with the air, after a preliminary blow with air. No steam is added during the last 1–2 min. In this way it is possible to prepare steel with nitrogen contents of the order of 0·005–0·009% with greater certainty than hitherto. This reduced nitrogen content is attributed to the lower finishing temperatures (the decomposition of steam is endothermic), the shorter refining

period, the more vigorous evolution of CO (carbon drop is faster than with air-blowing) and the reduced partial pressure of nitrogen in the gases. It appears that steel prepared in this manner can be used for many purposes for which up till now open-hearth steel has been specified. Because of the low finishing temperature, trouble has been experienced during teeming. It is hoped that this will be overcome by using oxygen as well as steam and so increasing the available heat.—J. P.

The Heat Balance of the Basic-Bessemer Converter when Blowing Pig Iron with Gases other than Air. E. Karwat. (Stahl und Eisen, 1950, vol. 70, Apr. 13, pp. 326–330). Starting from the experience that in the heat balance of an air-blown converter there is no excess of heat over that required to account for losses due to cooling, radiation, etc., equations for the yield of heat for blowing with oxygen, carbon dioxide and steam have been worked out. Then the composition of mixtures of oxygen and carbon dioxide or oxygen and steam which yield the same heat as air or oxygen-enriched air are given. A mixture of 49·5 cu.m. of oxygen with 36·0 cu.m. of CO_2 or a mixture of 48·5 cu.m. of oxygen with 51 kg. of steam has the same thermal effect as 309 cu.m. of air per ton of iron. Instead of 215 cu.m. of air with 30% oxygen, a mixture of 55·5 cu.m. of oxygen with 22·4 cu.m. of CO_2 or 55 cu.m. of oxygen with 31 kg. of steam is required per ton of iron. The water–gas equilibrium over liquid Fe–FeO controls the composition of the exit gases. The subsidiary burning of the reducing gases liberates considerable heat. Its employment permits an increase in the amount of added scrap and should have a favourable effect on the course of phosphorus and carbon removal. The energy requirements of the above processes are only slightly greater than that of air-blowing. They increase with the amount of scrap employed.—J. P.

The Effect of the Basic-Bessemer Process on the Development of Phosphate Fertilizers. G. Trömel and S. Gericke. (Stahl und Eisen, 1950, vol. 70, Apr. 13, pp. 330–332). The reactions by which basic-Bessemer slag and other phosphate fertilizers are produced are compared. The discovery that basic-Bessemer slag, although not containing water-soluble phosphate, had a beneficial effect on plant growth has radically altered the views on the mode of action of phosphate fertilizers. The presence of manganese in converter slag may be held to have prevented in Germany that decrease in agricultural yield which has resulted elsewhere from the absence of this vital trace element.—J. P.

The Bessemer Converter Process. A. B. Wilder. (Journal of Metals, 1949, vol. 1, Nov., pp. 22–27: Dec., pp. 20–28). The history and economic aspects of steel production in the Bessemer converter are discussed with particular emphasis on the acid process. The limitations of the process and the quality of converter steel are reviewed, and it is deduced that converter practice is inherently adaptable to the economic production of steel suitable for most of the applications of open-hearth steel. Various converter designs are described, including the 'turbo-hearth,' which is capable of producing steel of open-hearth quality from pig iron of composition normally used in the basic open-hearth process. The use of the spectrometer and photocell in controlling the end-point, and the possibility of measuring the metal temperature during the blow, are discussed. Data on the use of oxygen-enriched blast are given, the main advantages being reduced blowing time and increased use of scrap. The need for further experimental work is stressed in order that the possibilities of the process may be fully realized.—G. F.

Experimental Operation of a Basic-Lined Surface-Blown Hearth for Steel Production. C. E. Sims and F. L. Toy. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1950, vol. 188, pp. 694–708; Journal of Metals, 1950, Apr.). The design and construction of an experimental surface-blown basic-lined converter are described and illustrated, and the data of a series of 1000-lb. heats are given in which standard basic pig iron was surface blown with air jets, using 120–180 lb. of burnt lime per ton of iron to produce a basic slag. The processing period is about 12 min., depending on the air input, and the steels produced have an average composition of 0·03% C, 0·08% Mn, < 0·01% Si, 0·024% P, 0·021% S, and 0·003% N_2, no special hot-metal composition being required. The drop of the carbon flame is abrupt and no afterblow is necessary as phosphorus and sulphur, which can be eliminated to the extent of 97% and 50% respectively, are removed before the flame drops. The temperature is increased about 300° F. by the heat of reaction, and the air requirement is of the order of 18,000 cu. ft./ton of iron, blast pressure being less than 3 lb./sq. in. Ejection of material is controlled easily and the fumes produced are considerably less dense than in the acid-Bessemer process. The addition of carbon and alloying elements of some of the heats produced steels with mechanical properties comparable to open-hearth steels of similar composition. A series of special commercial-scale tests on heats of up to 30 tons is found to corroborate the findings of the experimental tests regarding the chemistry of the process and to emphasize the possibilities of the process, although many operating problems remain to be solved.—G. F.

Effect of Iron Quality on Bessemer Blowing Problems. R. E. Edwards. (Journal of Metals, 1950, vol. 188, May, pp. 736–743). Certain operating problems of the Bessemer process have been indirectly intensified by major changes in blast-furnace raw materials, namely: (1) Depletion of metallurgical coke, resulting in the use of a poorer-quality coke which can cause extreme variation in silicon and sulphur content of the iron; (2) depletion of low-phosphorus hematite ores, which in some cases have been replaced by lower iron content magnetite ores; and (3) depletion of low-manganese ores, resulting in an iron higher in manganese. The effect of these resulting changes in iron quality on the Bessemer operation is discussed, the chief problem considered being that of 'slopping' or the ejection of slag and metal from the converter during the blow. The chemical factors causing this are associated with slag characteristics, a thin fluid slag promoting it. Data showing the influence of iron composition on slag fluidity are presented; 'slopping tendency' decreases as silicon content of the iron increases, whilst increasing the manganese content causes a slight increase in 'slopping,' although neither element alone controls the problem. The Si/Mn ratio, however, is closely related to 'slopping,' which occurs on all casts with ratios of 1·0–1·3, but occurs to a less extent as the ratio increases and is completely absent with ratios above 4·2. Lime and magnesia have the most detrimental effect on slag consistency, but titanium, phosphorus, and sulphur have comparatively little effect. Iron oxide in the slag has an important effect on 'slopping,' and an increase from the normal 20% to about 30% caused heavy 'slopping.' The origin of these high iron oxide contents is not definitely established, but is associated with the use of magnetite sinter in the blast-furnace, which has also been found to coincide with the build-up of material on the converter lining with a detrimental effect on the operation. It is emphasized that changes in converter design and operation are necessary in view of the changes in iron quality, but that the problem could be reduced to some extent by changes in blast-furnace practice and by intermediate treatment of the iron.—G. F.

Side-blow Converter Process for the Production of Low Nitrogen Steel Ingots. R. R. Webster and H. T. Clark. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1950, vol. 188, pp. 778–790; Journal of Metals, 1950, May). The commercial possibilities of the side-blown converter process for the production of low-nitrogen steels are discussed, and a description is given of the operation of two acid converters, of 3 and 22 tons capacity, on a pilot-plant basis for a total of 214 heats. The method of blowing is varied during the trials, surface and sub-surface blowing, and combinations of the two, being employed. It is found that low-nitrogen steel possessing good cold-working properties can be produced within wide operating limits, particularly with surface blowing, whilst the carbon content of the steel is 0·01–0·05% higher, depending on the blowing method, than that of bottom-blown converter steel. A considerable degree of control can be obtained by varying the blowing practice, and it appears that a combination of surface blowing for most of the period with sub-surface blowing at the finish is the best method of producing low-carbon low-nitrogen steel by this process. The high temperatures obtained enable larger amounts of scrap or ore to be used in the charge than in bottom-blowing, but the slag, being hotter and higher in iron oxide, is less viscous and causes more rapid lining wear. Blowing lossess vary widely, but under the best conditions are comparable to bottom-blowing practice. There appears to be no inherent limitation on the size of the charge, wide

changes in which do not require any major change in operation; for instance, the 3-ton converter handled a charge of 11 tons of iron successfully. The trials indicate that the process has distinct possibilities, but it is emphasized that a number of complex operating problems, notably those of slag control and optimum blowing conditions, remain to be solved before it can be considered a commercial success.—G. F.

Oxygen Enrichment of the Blast in Basic Bessemer Steelmaking. P. Coheur, L. Marbais, and A. Grosjean. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Sept., pp. 693–699). A series of rimming steels was made with up to 30% of oxygen added to the blast and additions of scrap or ore. Factors varied were the percentage of oxygen, amount of lime, and the time and nature of additions. The nitrogen in the steel was lowered from 0·01% to 0·008% (with scrap addition) and to 0·005% (with ore addition). Dephosphorization was improved but there was little change in the sulphur. There is a gain of 38% on converting time, and 19% on the total cycle is reported.—A. G.

Manufacture of Basic-Bessemer Steel of High Quality. P. Coheur, L. Marbais, and J. Daubersy. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Apr., pp. 104–108). Details are given of work carried out on a 15-ton converter using a blast either of oxygen-enriched air or of an oxygen–steam mixture. Reduction of the nitrogen content of the steel to below that of open-hearth steel with a simultaneous reduction in sulphur and phosphorus has been found possible.—B. G. B.

Results Obtained by the Use of Oxygen in Basic-Bessemer Practice in the Liége District. A. Desoer. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Aug., pp. 213–221). Details are given of full-scale research work carried out at the steelworks of the Société John Cockerill, Société d'Ougrée-Marihaye, and the Société d'Espérance-Longdoz on the use of oxygen. The addition of scrap iron, Swedish iron ore, and limestone slag to a converter and the use of an oxygen–steam blast has also been investigated. The use of oxygen is practical and enables a reduction in the nitrogen content of the steel and a quality approaching that of open-hearth steel to be obtained.—B. G. B.

Oxygen-Enrichment of the Blast for a Basic-Bessemer Converter. L. Marbais and M. Nepper. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Oct., pp. 325–330). The use of oxygen in the blast to the Bessemer converter has enabled steel to be produced having cold-working properties superior to those normally obtained. The nitrogen content of the steel has been reduced to 0·0058% which is equal to that of a normal open-hearth steel. This reduction of nitrogen is said to be the reason for the improved cold-working properties. The quality of the steel is, however, not equal to that of open-hearth furnace steel.—B. G. B.

The Use of Oxygen-Enriched Air in the Operation of Bessemer Converters. V. Zsák. (Bányászati és Kohászati Lapok, 1950, vol. 5, July, pp. 413–420). [In Hungarian]. The author investigates the factors influencing the decarburization of the charge in open-hearth furnaces and converters and calculates the heat generated by the combustion of the various substances in the pig iron when its temperature is increased to 1300° C. These calculations are made for Bessemer converters blowing ordinary air and for 30% and 35% oxygen-enriched air. The importance of application of an oxygen-enriched blast for steel production by the duplex process is discussed.—E. G.

The Problem of the Improvement of Basic-Bessemer Steel. J. Wurth. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Aug., pp. 208–213). Details are given of work carried out at the Société John Cockerill. Variation of the converter shape, use of side-blown converters, replacement of part of the air blown by iron ore or mill scale, addition of oxygen together with ore, scrap, or CO_2, use of a double slag, treatment with deoxidants, and treatment of the liquid steel in an electric furnace have all been investigated. Each of the above variables has advantages and disadvantages, which are reported, and by combination of two or more an improvement in steel quality has been obtained.—B. G. B.

Oxygen in the Converter Process. A. Ludkiewicz and J. Natkaniec. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 1, pp. 71–79). [In Polish]. The advantages of using oxygen in the basic converter process are outlined in the light of study of the theory and of results of full-scale tests. The blowing time can be shortened and the output increased. Owing to the increase of temperature more scrap can be used. The content of nitrogen in the steel is lower. Oxygen makes possible the use of pig irons which normally are unsuitable for melting. The diagram and the approximate equations are given for the relation between the oxygen enrichment and the phosphorus content in the iron. The addition of 1% of oxygen to the blast increases the temperature of the bath by about 20 to 40° C.—W. J. W.

The Present State and the Future Development of the Basic-Bessemer Process. F. Meunier. (Revue Technique Luxembourgeoise, 1950, vol. 42, Apr.–June, pp. 89–102). After a short historical survey, the author reviews the present state of the process as operated in Luxembourg today. Details are given of research now being undertaken to improve basic-Bessemer steel.—B. G. B.

Some Notes on Heat Problems in Steelworks. P. Löfström. (Jernkontorets Annaler, 1950, vol. 134, No. 1, pp. 24–40). [In Swedish]. Heat losses and heat recovery in open-hearth and reheating furnaces have been studied in a medium-sized Swedish steel plant. The furnaces in steel plants and rolling mills are generally working with low efficiency. The heat losses may be referred to one or more of the following causes: The nature of the heating process, inappropriate construction and design, and deficient operation and control. Thermal losses in flue gases are inevitable, but could be partly recovered for preheating air and for secondary heat requirements. The latter alternative seems to be the best for open-hearth furnaces, whilst the former is more suitable for reheating furnaces. Among other causes of heat loss are gas leakage, air infiltration, incomplete combustion, and heat transfer outside the furnace. With regard to incomplete combustion it is important to use burners which permit a correct fuel/air ratio at different burning intensities. Large furnace units should also be provided with instruments for flue gas control. The fuel consumption as a function of the load has a marked influence on the cost of heating, especially in reheating furnaces for rolling mills and forging plants where the rate of production is governed by the mechanical equipment. In order to obtain high efficiency in heating it is advisable to use furnace designs which permit rapid heating right through the material, and the normal rate of heating should be kept as close to the maximum rate as possible.—B. S. E.

Relative Deoxidizing Powers of Some Deoxidizers for Steel. C. E. Sims, H. A. Saller, and F. W. Boulger. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1949, vol. 185, pp. 814–824; Journal of Metals, 1949, vol. 1, Nov.). A comparison is made of the relative deoxidizing powers of several steels, based on the minimum amount of each element required to bring about the sharply defined change in the shape of the sulphide inclusions from the large globular type to the eutectic type. The base steel contained C 0·25–0·30%, Mn 0·50–0·70%, and Si 0·30–0·40%. Manganese, silicon, vanadium, and calcium are shown to be ineffective in producing eutectic sulphides, the strongest deoxidizers, in decreasing order of effectiveness, being aluminium, zirconium, titanium, and boron. A tentative theory on the deoxidation reaction and the formation of oxide inclusions is given, with notes on the Al–O, Zr–O, and Cr–O equilibria.—G. F.

Slag and Removal of Elements in the Basic Open-Hearth Process. Analysis Based on Statistical Methods. E. Bucko. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 2, pp. 137–167). [In Polish]. The results of chemical analyses of a basic slag have been studied with the aid of statical analysis, for 44 heats, from 20 to 50-ton open-hearth furnaces, working on cold charges. The charge was low in phosphorus (about 0·19%) and giving low P_2O_5 in the slag (usually below 4%). The relation between the composition of the slag and its basicity is discussed.—V. G.

Faster Open Hearth Charging. V. W. Jones. (Journal of Metals, 1950, vol. 188, May, pp. 744–745). A description is given of a new scrap-handling and charging technique at the Armco Steel Corp. (Middletown, Ohio), which permits the charging of a 225-ton heat of 70% scrap in 1½ hr. The success of the technique depends on the method of transporting the scrap pans to and from the furnace stage, each furnace being provided with a storage truck for loaded scrap pans, which are lifted to stage level by a hoist at one end of the furnace and returned by another hoist at the other end. No interference is caused by two adjacent furnaces charging at the same time.—G. F.

Is It Really Necessary to Use a Carburized Gas Flame for Heating Open-Hearth Furnaces? A. Náhoczky. (Bányászati és Kohászati Lapok, 1950, vol. 5, June, pp. 366–374). [In Hungarian]. Successful experiments in heating a 35-ton open-hearth furnace by the flameless combustion of a detarred producer gas have led the author to examine whether a flame is really necessary for the melting of steel in open-hearth furnaces. The influence of the following factors affecting combustion is discussed: (1) Burner design, (2) gas quality, (3) preheating, (4) release of heat, and (5) furnace efficiency. Carburization with heavy hydrocarbons and the use of blast-furnace gas mixed with oxygen-enriched air are dealt with, and development trends in Hungarian steelworks are outlined.—E.G.

The Metallurgical Conditions to be Fulfilled to Produce Good Quality Steels. S. Bán. (Bányászati és Kohászati Lapok, 1950, vol. 5, Aug., pp. 468–478). [In Hungarian]. The author describes the problems to be solved to obtain efficient production of good quality steel in Hungary, and deals with the causes of the production of defective steel. The two main failures appear to be laminations in the steel plate for boilers and the formation of hair-line cracks in shafts. The Russian Professor I. P. Bardin criticized the technical standard of the Hungarian iron and steel industry very severely and emphasized that it must be completely overhauled in order to raise the efficiency to a level comparable with that of modern industries of other countries.—E. G.

How to Conserve Manganese. J. C. Vignos. (Journal of Metals, 1949, vol. 1, Nov., pp. 20–21). At present about 70% of the total manganese used in the American iron and steel industry is wasted in flush-off and tapping slags, and suggestions for reducing this wastage are briefly outlined. Additions to the ladle, rather than to the bath, and a greater use of silicon are advocated in the production of killed steels, and brief mention is made of suggested methods of recovering manganese from slag dumps.—G. F.

The Perrin Process. R. Perrin. (Jernkontorets Annaler, 1950, vol. 134, No. 1, pp. 1–23). [In Swedish]. The author outlines his process, which is essentially the deoxidation and desulphurization of steel by mixing it with molten slag in a ladle. The qualitative characteristics related to different steel-melting methods are more or less insignificant as the final composition and properties of the steel depend chiefly on the slag reactions. 'Parasite' slag should be excluded and the slag used for the treatment should be smelted separately in a small electric furnace. Slags high in alumina are recommended, *e.g.*, a composition of 43% Al_2O_3, 3% SiO_2, 53% CaO, and less than 1% FeO. A fine grain steel free from slag can only be obtained if aluminium has been introduced into the steel by reduction of alumina present in the slag. The used slag can be utilized as a low-grade cement or as raw material for aluminous cements. It is also valuable in the Petersen process for aluminium production. The Perrin process is said to give several advantages when applied in combination with most steel-smelting processes; it yields high and reliable quality of products with low oxygen and sulphur contents, even when impure raw materials are used.—B. S. E.

Oxygen Refining in the Open-Hearth Furnace. L. Bernard and R. Ferry. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Aug., pp. 573–581). At the Creusot works with their producer-gas-fired furnaces, oxygen is supplied to the slag–metal interface at rates > 280 cu. ft./min. The rate of carbon removal is increased from 0·0045% to 0·008%/min. but is also dependent on initial carbon content, temperature, and degree of slag oxidation. The effect on slag composition and on the phosphorus, sulphur, and manganese content of the bath is also studied. Advantages gained are: Quicker heating and refining; reduced loss of manganese; and an economy of 3% (allowing for cost of producing oxygen). The quality of the iron is unimpaired.—A. G.

Acid Bessemer Hot Metal in Basic Open-Hearth Steel Manufacture. C. E. Makepeace. (Canadian Mining Journal, 1950, vol. 71, Sept., pp. 63–78). A study of the modified duplex process revealed that the thermochemical efficiency of the acid-Bessemer converter was better than that of the basic open-hearth furnace in the ratio of 1:3·9, and that the converter reduced the silicon content of the mixer metal from 1·6% to 0·001%. If low-silicon hot metal from the converter was used in the basic open-hearth furnace, there was a reduction in slag volume of 21,420 lb., and this lower slag volume facilitated transfer of heat to the bath, increased the steel capacity of the furnace, and increased the ability of the furnace to oxidize the bath. Reduction of silicon in the charge also effected a flux saving of 5 tons, and to ensure this reduction, blast-furnace and Bessemer slag must be eliminated as far as possible from the hot-metal charge. In addition the life of the furnace refractories will be increased. The use of Bessemer metal led to an increase in production rate of 3·48 short tons/hr. Loss of manganese in the converter was calculated and an addition of approximately 359 lb. of manganese was needed for each heat of steel made in the open-hearth furnace. The iron loss amounted to about 8·3%. The following properties of as-rolled steel (rail sections), made with Bessemer metal refined in the open-hearth furnace were found to be satisfactory: yield point, tensile strength, elongation, reduction of area, toughness, ageing, temper brittleness, and susceptibility to hydrogen flakes. Nitrogen content was from 0·006% to 0·011%, which is considered satisfactory.

T. E. D.

Use of Oxygen in Electric Alloy-Steel Production. (Engineering, 1950, vol. 169, June 9, pp. 660–661). The practice for melting charges of 100% stainless steel scrap in a 5-ton arc furnace at the works of Edgar Allen and Co., Ltd., is described. When melting with the arc is completed, oxygen is blown in through a ¾-in. pipe or lance. After oxidizing the carbon, additions of ferrosilicon, ferrochromium, or 'silicon–chrome' are made to reduce the oxidized chromium in the slag and pass it back to the molten metal; this is done with a loss of only about 4% chromium. The temperature rises to about 1750° C. The time from charging to tapping is about 6–7 hr. A similar process has been developed by the Brymbo Steel Co., Ltd., Brymbo, near Wrexham, for the production of low-carbon alloy steels.—R. A. R.

Manganese Recovery in Acid Electric Steelmaking. S. F. Carter. (American Foundrymen's Society, 1950, Preprint No. 5). Factors affecting manganese recovery have been investigated by correlating concurrent metal and slag analysis before and after the manganese addition. Data from acid and basic electric furnace practice are examined. Extremes in slag composition were artificially created by draining the original slag and adding synthetic slag mixtures of various predetermined ratios. Single-slag heats of normal manganese content and of higher manganese content, double slags low in FeO, high in lime, and high in MnO were investigated. Slag composition, desired metal analysis, temperature, slag fluidity, quantity of slag, ladle additions, and the influence of oxygen on these factors, were studied. The application of these data to better manganese recovery and improved manganese control is discussed.—J. C. R.

Electrode Control and Associated Operating Mechanisms. E. A. Hanff. (Transactions of the American Institute of Electrical Engineers, 1950, vol. 69, Part I, pp. 567–570). Limit switches and safety stops to control the movement of vertical electrodes in arc furnaces are described.—R. A. R.

Tool Steel. D. C. Harris. (ESC News, 1950, vol. 4, Summer Issue, pp. 2–7). After commenting on the characteristics of high-speed steel, the author briefly describes its manufacture and heat-treatment.—R. A. R.

Ingot Heat Conservation—Mould and Ingot Surface Temperature Measurements. A. V. Brancker. (Journal of The Iron and Steel Institute, 1950, vol. 165, July, pp. 307–313). Surface temperatures have been measured at 36 positions on the four sides of a mould. These measurements extended from teeming to stripping. Two complete sets of temperature data were obtained for two different mould positions in a casting pit during two separate top teeming operations. In each test, immediately the ingots were stripped, temperatures were measured with an optical pyrometer. Temperature continuity was therefore maintained until the ingots were charged to the soaking pits. Significant differences were found between the temperatures on the faces of each mould, and also between the two mould positions.

Ingot Heat Conservation—Some Methods of Calculating Internal Temperatures from Surface Temperatures of Ingots. (Journal of The Iron and Steel Institute, 1950, vol. 166, Sept., pp. 71–76). Methods are given for the calculation of the internal temperatures of ingots (*a*) by the use of the theoretical equation for a solid with known and constant thermal properties and initially at a uniform temperature, which is heating or cooling in surroundings at constant

temperature ; (*b*) by surface temperature measurements when the thermal properties are unknown but are assumed constant (this method is derived from the theoretical equation, and is subject to the same limitations) ; and (*c*) by an empirical equation using measured surface temperatures.

The Distribution of Temperature in Ingot Moulds and Its Relation to Ingot Structure. I. M. Mackenzie and A. Donald. (Journal of The Iron and Steel Institute, 1950, vol. 166, Sept., pp. 19–28). A 3-ton ingot of mild steel fully killed with silicon and aluminium was sectioned, and the sub-surface structure was examined by sulphur printing and macro-etching. The effect of convection currents in the superheated metal giving rise to banding of dendrites near the surface is discussed. An experiment to show the effect of ' overkilling ' with aluminium and silicon in producing axial porosity is described.

Experiments to determine the changing temperature distribution within the ingot mould wall are described, and the results obtained are used in a calculation of the rate of heat transfer to the mould. It is shown that the rate of heat transfer is initially at a maximum value which may exceed 2000 cal./sq. cm./min., the rate decreasing to about one-tenth of this value within ten minutes. A graphical method of successive approximations is used to calculate the rate of solidification of the ingot. It is shown that while the thickness of the solid skin may be given approximately by an expression of the form : skin thickness = constant$\sqrt{\text{time}}$, this function is only empirical and it does not hold over the first few minutes after teeming.

The factors controlling the rate of heat transfer to the mould are discussed with particular reference to the early separation of the ingot skin from the mould wall. The experimental data and the results of the approximate calculations are made the basis of hypotheses of the mechanism of solidification and of the formation of ingot cracks. It is suggested that cracks are most likely to form during the first few minutes after teeming because of the rapid expansion of the mould and the consequent stretching of the newly formed ingot skin. A postulated mechanism is shown to explain the observed effects of superheat, teeming speed, and sulphur content on the incidence of cracking.

Hot Top Efficiency Improved. J. W. Mueller and G. A. Bole. (Steel, 1950, vol. 126, Jan. 23, pp. 80, 82, 84). Results of research on ingot-mould hot tops at Engineering Experiment Station, Ohio State University are reported. *See* " A Progress Report on Hot-Top Research," Journ. I. and S.I., 1950, vol. 165, July, p. 347.—R. A. R.

Solidification of Ingots. B. H. Alexander. (American Foundrymen's Society, 1950, Preprint No. 3). The conventional dumping method was used to determine solidification rates, duralumin and aluminium being used for the experiments. The following conclusions were reached : (1) Solidification curves of ingots do not obey Field's equation over the whole range of freezing. In the later stages there is a deviation resulting in a more rapid rate of freezing than would be expected according to Field's equation ; (2) overheating of the liquid metal before pouring causes a delay in the beginning of freezing and an increase in the time necessary for complete solidification ; and (3) the dumping method does not give a measure of the volume or mass velocity of freezing for ordinary metals and alloys.—J. C. R.

PRODUCTION OF FERRO-ALLOYS

Ferroalloys in 1949. R. G. Knickerbocker. (Journal of Metals, 1950, vol. 188, Mar., pp. 476B–476D). A brief survey of the research and development in the field of ferro-alloys during 1949 is presented, together with data on the tonnages produced and the main producing firms. Chief emphasis is placed on manganese, and the increasing interest in methods of recovering manganese from open-hearth slags is indicated. Other ferro-alloys considered are those containing chromium, cobalt, nickel, molybdenum, tungsten, columbium, tantalum, vanadium, titanium, and the exothermic alloys Chrom-X and Chrom-Sil-X.—G. F.

Electrolytic Manganese Production. B. Sandberg. (Jernkontorets Annaler, 1950, vol. 134, No. 4, pp. 172–188). [In Swedish]. The author surveys the Electro-Manganese Corp. process for the electroytic production of manganese as applied at Knoxville, Tenn., and the Bureau of Mines' experimental plant at Boulder City, Nev. The bulk of the manganese content of the ore is present as MnO_2 and this is reduced to MnO in rotary kilns, employing oil as reducing agent. After leaching with H_2SO_4, the solution is purified with H_2S and $FeSO_4$ followed by aeration, then the solution is electrolysed in diaphragm cells, the used katolyte being fed back to the leaching batteries. Additions of organic 'gloss promoters' to the electrolyte proved detrimental or useless in the electrolytic process. An account of the present use of electrolytic manganese is given and the future applications in Swedish industry are discussed. There are 69 references.—B. S. E.

Investigation on Electrolytic Deposition of Manganese. Part II. M. Perec. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 2, pp. 93–98). The effect of F^{++}, Fe^{+++}, Pb^{++}, Ni^{++} and Cu^{++} ions on current efficiency during the electrolytic deposition of manganese was investigated. It was found that in 5 hr. electrolysis the concentration of Co^{++} 1–1·5 mg./l., or Ni^{++} 2·5 mg./l., lowers the current efficiency by about 50% and that the most detrimental impurity is cobalt, which at a concentration of 2·0 mg./l dissolves nearly all the manganese. The measurements of potentials on electrodes with partially dissolved manganese have shown that at *p*H 8 cobalt deposits are cathodic and a cell is set up in which manganese, being an anode, dissolves. The cathode polarization curves were measured for a manganese bath with cobalt additions, and for ammonium sulphate and sodium sulphite baths. In the first case cobalt decreases polarization and in the second the deposited cobalt sponge diminishes the hydrogen overvoltage. Consequently in the case of small quantities of cobalt impurities in a bath, a hydrogen–manganese cell is set up, in which manganese acts as anode.

A rapid polarographic method of determining cobalt while preparing the electrolyte for the hydrometallurgy of manganese has been developed.—V. G.

Energy Production in Three-Phase Low-Shaft Furnaces for the Production of Ferrosilicon. G. Volkert and E. Schwarz von Bergkampf. (Stahl und Eisen, 1950, vol. 70, Apr. 27, pp. 369–371). The effects of different conditions in the production of ferrosilicon are compared. The working, and thus the current consumption, of a furnace vary with the shape of the melting zones under and around the electrodes. It is shown that an arc furnace will work efficiently only under certain conditions of voltage, depending on its size and the properties of the burden.—J. P.

Preparation of Manganese Slags for the Production of High Percentage Ferromanganese by Blowing Spiegel Iron. T. Kootz, J. Willems, W. Oelsen, and H. Wentrup. (Stahl und Eisen, 1950, vol. 70, Apr. 27, pp. 360–369). The effects of temperature, composition and physical nature of slag, composition of the iron, and time of blowing on the slagging of manganese and on the Mn/Fe and Mn/P ratios in the slag have been studied by observations and analyses of samples from a large number of experimental runs in a converter. The following conclusions have been drawn: It is not possible to specify a single satisfactory method for the blowing of spiegel iron, since the process must be varied for irons of high or low phosphorus content and related to the use to which the intermediate metal is to be put. When blowing a phosphorus-rich manganese iron, it is expedient to work with a liquid silica-rich slag because then the iron and phosphorus contents of the slag are low and the dispersed metal in the slag is usually below 5%. The Mn/Si ratio in the iron should be between 2·5 and 4 and the temperature should be held at 1400° C., blowing being continued only until the carbon begins to burn off. From 10 to 15% of ore, mill-scale or phosphorus spiegel iron may be added at the beginning of the blow to act as a cooling agent. If it is possible to separate the dispersed metal from the slag by magnetic treatment, it is better to remove the manganese with a pasty or crumbly slag. In order to maintain a low phosphorus content in the slag the temperature must be above 1600° C.; in this case the iron content is appreciably higher than with liquid slags at 1400° C. When blowing a spiegel iron of low phosphorus content, it is not desirable to employ a silica-rich slag since the phosphorus content of the slag is generally low and the high silica content makes reduction to manganese metal in the blast-furnace difficult. The iron should have preferably silicon 0·3–1·0% and manganese 6–12%. With this low silicon content the slag should be pasty or crumbly. If the intermediate metal is to be

returned to the mixer, a temperature of 1500° C. is most suitable, whilst if it is to be blown to steel or used as duplex metal, temperatures of 1650–1700° C. must be employed. The intermediate metal should not be blown to less than 1·5–2·0% manganese as otherwise the iron will be too high and the Mn/Fe ratio unfavourable. Ore or scrap is the best material to use for cooling. Although when blowing at low temperatures, volatilization loss is not significant, it may amount to as much as 20% at high temperatures. Additions of lime have a detrimental effect on manganese slagging and on the Mn/Fe ratio. If the crumbly slag is to be used to produce high-percentage ferromanganese, the dispersed metal must be removed with a magnetic separator.—J. P.

Alsithermic Metallurgy. A. Paoloni. (Journal du Four Electrique, 1950, vol. 19, Jan.–Feb., pp. 18–20; Mar.–Apr., pp. 44–56). This paper sets out to show, on an experimental basis, that instead of the usual method of using carbon as reducing agent, it is possible to use an alloy composed of 50% of aluminium, 35% of silicon, 10% of iron, 3% of titanium, the rest being carbon, calcium, phosphorus, and sulphur. This alloy is called an alsithermic reducing agent, and with it, it is possible to achieve aluminothermic and silicothermic reactions at the same time.—J. A. L.

FOUNDRY PRACTICE

Production Planning and Quality Control in Foundries. A. Mandoki. (Öntöde, 1950, vol. 1, May, pp. 97–108: Bányászati és Kohászati Lapok, 1950, vol. 5, May). [In Hungarian]. The problems of production planning and quality control in Hungarian foundries are reviewed. In the discussion J. Dauda mentioned that about 50% of casting rejects are due to minor types of negligence which are difficult to deal with because the available experts are fully occupied with eliminating production bottlenecks. These rejects could be eliminated by establishing independent and satisfactory quality control and by stopping skilled foundrymen doing unskilled work.—E. G.

Treatment of Metals in Foundries. J. Sequens. (Hutnické Listy, 1950, vol. 5, July, pp. 286–289). [In Czech]. The influence of physico-chemical processes during melting and casting which affect the quality of castings is discussed. The author stresses that vacuum furnaces should only be used when there is a great difference between the boiling and melting points of the metal. Ellingham's affinity diagrams for oxygen and sulphur are included; these can be corrected for the working pressure. These diagrams are useful for selecting deoxidizing and desulphurizing reagents. If the reaction products are solid and dense they may cover the surface and slow down the reaction, but not if they are gaseous or liquid. E. G.

The "Metallurgical Blast Cupola." R. Doat. (Italian Metallurgical Association: Foundry Trade Journal, 1950, vol. 89, Aug. 31, pp. 229–232). The 'metallurgical blast cupola,' which closely resembles a miniature hot-blast furnace, has, for over a year, been producing over 1200 metric tons of iron per month. Its feature is that it permits of the production of metals having very different properties from those charged. Slag control, with resultant sulphur removal, is possible, and metallic losses, due to the reducing atmosphere operating, are virtually nil. In addition, despite coke of poor quality, the metal is tapped out at temperatures above 1500° C., and this is combined with low refractory losses. For efficient operation the plant requires a high-grade supervisory staff. Iron for spun pipes can be made from only steel and scrap charges; high-duty cast irons from 80–85% steel scrap charges; and heat-resisting cast irons from 100% steel scrap and ferrosilicon, 0·8% of chromium being added in the ladle.—J. E. W.

Carbon Control of Cupola-Melted Irons. E. Bramble. (Foundry Trade Journal, 1950, vol. 89, Aug. 24, pp. 217–218). Accurate control of carbon in cupola melting ensures uniformity of casting characteristics and machinability. The principal factors affecting carbon content are: (1) Composition and type of materials charged; (2) method of charging; (3) height of coke bed; (4) amount and type of coke charged; (5) volume and pressure of air blast; (6) temperature attained in the cupola; (7) slag control and disposal; and (8) type and design of cupola.—J. E. W.

Modern Charging Practice for Cupolas. F. Fischer. (Neue Giesserei, 1950, vol. 37, Feb. 23, pp. 77–78). The use of mechanical charging rather than charging by hand is advocated. Several suitable installations are briefly described and illustrated.—O. H. G.

Synthetic Pig Iron from Steel Scrap, Made in a Cupola Working on Charcoal. M. Czyzewski. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 2, pp. 123–136). [In Polish]. By remelting steel scrap in a cupola with three or five rows of tuyeres, working on charcoal, a charcoal pig iron with 2·8% to 3·7% of carbon can be obtained. The carbon content of charcoal pig iron depends mainly on the quality of the blast. By means of experimental heats, the degree of carburization of steel in different zones of the cupola has been determined.—V. G.

The Production of Nodular Cast Iron without Inoculation with Magnesium or Cerium. H. Thyssen and F. Gaty. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Mar., pp. 57–62). By careful control of physical conditions completely spherical graphite nodules can be obtained without the additives normally employed. Inoculation with calcium-silicon has made it possible to obtain practically complete nodulization of the graphite in the iron even in the presence of 0·9% of phosphorus. The necessity for ensuring efficient mixing after inoculation is stressed.—B. G. B.

The Belgian Contribution to the Study of Nodular Iron. A. De Sy. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Aug., pp. 269–277). The results of new methods of obtaining nodular iron using lithium, calcium, barium, and strontium are given. The first results are reported of the use of the electron microscope to study the formation of graphite spheres in hypo-eutectic nodular iron treated with magnesium. The author discusses the application of magnesium to the manufacture of nodular iron.—B. G. B.

Nodular Cast Iron. G. Vennerholm, H. Bogart, and R. Melmoth. (Society of Automotive Engineers: Foundry Trade Journal, 1950, vol. 88, Mar. 9, pp. 247–256). The authors present an evaluation of the present state of development of nodular cast iron. Methods of manufacture are discussed and include the use of a magnesium/copper/ferrosilicon alloy. A minimum of 0·035% of magnesium must be present, for complete spheroidization to occur; amounts in excess of 0·1% result in a stable white iron. The effect of composition on the tensile strength and ductility of the iron is pointed out. Applications of nodular-type irons are also considered; these include the hot rolling, in two heatings, at approximately 955° C. of 3-in. cast slabs, down to $\frac{7}{16}$-in. plate, the resultant tensile strength being 62 tons/sq. in. with an elongation of 4%.—J. E. W.

Influence of Some Elements upon the Formation of Nodular Graphite in Cast Iron. P. P. Petrosyan and S. E. Shoi-Shakhbudagyan. (Doklady Akademii Nauk S.S.S.R., 1950, vol. 71, No. 1, pp. 123–125). The effect of silicon, manganese, sulphur, and phosphorus, as well as the rate of cooling on the nature and shape of the graphite in magnesium-treated grey iron was investigated. Changes in the silicon content did not produce any major alteration in the shape of the graphite, neither did changes in the manganese content in the 0·6 to 7% range; phosphorus contents in the 0·12 to 0·5% range did not affect the precipitation of globular graphite. Varying the cooling rate over a wide range also had no effect.—R. A. R.

The Production of Malleable Iron Castings. A. J. Anderson. (Australian Institute of Metals: Australasian Engineer, 1950, Mar. 7, pp. 69–75). The subject is discussed under the subheadings: Manufacture of Patterns, Core Production, Moulds, Production of Molten Metal, Annealing, Testing, and the Effect of Chemical Composition. Metal patterns are preferred to wooden ones when the number of castings makes their use economical. Four methods of producing cores are described, and typical sand mixtures and their properties are quoted in each case. Core drying is usually carried out at 400–450° F., with the time depending on size. The surface finish of the casting depends upon the grain size and composition of the moulding sand, three different compositions together with their properties being quoted as typical examples. The cupola is used for melting the metal. Steel scrap should be clean and free from alloying elements, especially silicon, aluminium, nickel, and copper which promote graphitization, and manganese, molybdenum, and chromium, which are carbide stabilizers. The classes of pig

iron, limestone, and coke are also specified. When pouring the metal direct from the cupola the temperature is about 1450° to 1470° C. and the carbon content 3 to 3·1%. When the duplex process is used the temperature is 1490° C. to 1515° C. and the carbon content 2·60% to 2·70%. The silicon content in the latter case is 0·90 to 1·00% and somewhat lower than this in the former. The annealing process consists of packing, heating to, and holding at, 1700–1800° C. at which temperature primary graphitization occurs, and finally cooling at 10° F./hr. to below the critical range. Typical properties are 22–30 tons/sq. in. tensile strength, 10–14% elongation on 2 in., and unbroken at 45° to 180° in the bend test. The properties of various grades are also considered in relation to the properties of the constituents, graphite, cementite, pearlite, and ferrite. The effects of carbon, silicon, sulphur, and manganese on the castability and rate of graphitization are dealt with, and finally the mechanism of graphitization during the annealing process is fully explained.—P. M. C.

Casting of Steel in Green Sand Moulds. N.-A. Berglund (Jernkontorets Annaler, 1950, vol. 134, No. 2, pp. 41–83). [In Swedish]. This report gives data on trials carried out in 1948–1949 at Domnarvfets Jernverk which were based on a number of laboratory castings. Special test pieces were designed which were given such a form and were cast in such a way that they would be sensitive to those defects which might be likely to arise with green sand moulds. These test pieces gave valuable information regarding the conditions under which such defects as swells, adhesion, gas holes, scabs, sand holes, and sand inclusions arise. They also gave information about how moulding procedure, casting temperature, and deoxidation of the steel may influence the result. The experience gained was subsequently applied to full-scale casting and in most cases good results were obtained. In the moulds tested only new sand was used. Sandstone sand proved to be the best material and a minor admixture of silica flour was advantageous, whilst glass sand or fine quartzite was not beneficial. As binders, 5% of bentonite and 1% of sulphite lye were useful, and an addition of 0·08–0·15% Al to the steel prevented holes in the castings, especially in the case of a mould with more than 5% of moisture.

B. S. E.

Gating Systems. V. Oliverius. (Hutnické Listy, 1950, vol. 5, Aug., pp. 321–325). [In Czech]. The factors to be taken into consideration in the design of ingates are discussed, *e.g.*, the velocity and path of the liquid metal, and the fact that casting is a hydrodynamic and not a hydrostatic process. The author recommends tangential gates and a larger number of ingates so as to obtain a better distribution of the liquid metal. The paper also includes information on Russian gating practice.—E. G.

Moulding Technique Aids Production. S. R. Bridger. (Institute of British Foundrymen: Foundry Trade Journal, 1950, vol. 88, Feb. 23, pp. 195–200). Examples are given of developments in moulding and coremaking techniques which have resulted in improved production rates and a better yield in sound castings.—J. C. R.

Technical Report on Practical Methods of Reducing the Amount of Fumes from Oil Bonded Cores. (Factory Department, Ministry of Labour and National Service, 1950: H.M. Stationery Office). The recommendations made in this 10-page report by the Joint Standing Committee on Conditions in Iron Foundries include the following: (1) Attention should always be given to the technical control of operations in all core shops; (2) the importance of mixing operations should not be underestimated; (3) a high standard of good housekeeping should be maintained; (4) the number of mixtures used should be reduced to a minimum; (5) all operators should have full and clear instructions; (6) the extravagant use of binders is to be avoided; and (7) the suppliers should be consulted in the choice and use of binders. Other recommendations deal specifically with storage, sand, mixing, baking, casting, types of core, and core block moulding.

R. A. R.

Modern Core Ovens. C. H. Barnett. (Industrial Heating, 1950, vol. 17, July, pp. 1231–1236). The author stresses the importance of the core department in a modern foundry. He discusses temperature, baking time, oven atmosphere and the gas recirculating system as being important factors in the baking process. He also discusses the merits of various types of fuel.—J. A. L.

Moulds Dried Rapidly and Uniformly in Car Type Oven. (Industrial Heating, 1950, vol. 17, Mar., pp. 490–494). A description is given of the installation of a car-type oven in the grey iron foundry of T. Shriver and Co., Inc., Harrison, N.J., in which sand moulds and cores are dried. The inside space is 12 ft. wide by 14 ft. 4 in. long and 8 ft. high. Heat is supplied by a Rockwell external direct gas-fired air heater. The oven is ventilated by a motor-driven exhaust fan. The adequacy of the heating system and controls has been demonstrated by the quality of the castings. Cleaning costs have been reduced as a result of cleaner stripping of castings from the dried moulds.—J. A. L.

Electronics Speed Core Drying. J. Dawson. (Iron Age, 1950, vol. 165, May 4, pp. 90–93). The author describes a dielectric type of heater. Synthetic types of resin binder may be used and advantages claimed are greatly reduced heating costs, no burning or overbaking, shorter baking period, and cores emerging from dryer at 200° F.—A. M. F.

Casting Large Rolls. L. Banhegyi. (Öntöde, 1950, vol. 1, June, pp. 126–130; July, pp. 155–158: Bányászati és Kohászati Lapok, 1950, vol. 5, June–July). [In Hungarian]. The author discusses problems in the production of large rolls in Hungarian foundries. To eliminate excessive internal stresses the author advocates a charge low in carbon and silicon. Experiments were carried out with charges of 60% steel scrap and 40% pig iron; the casting time was about 40 sec. and the casting temperature 1200° to 1250° C. After casting, dry fine sand was used to cover the moulds to obtain slow cooling. Further experiments are being carried out to improve the Hungarian casting technique so as to increase the home production of rolls for rolling mills and reduce imports.—E. G.

The Use of Alloying Elements in Chilled Iron Rolls. A. Allison. (Metallurgia, 1950, vol. 42, June, pp. 9–13; July, pp. 63–66. Methods are described by which chilled alloyed iron rolls have been recently manufactured. It is pointed out that plain iron rolls of this type are very delicate and unpredictable structures, and that the advantages of greater hardness obtained by alloying were often offset by their even more temperamental behaviour in cracking and other failures. Various devices used in casting and heat-treating such rolls so as to get the best results are described; these include the generation of large centrifugal forces in the casting process by pouring in the metal from a greater height than usual, thus producing a very clean surface. In the second part the structure of chilled rolls both of plain and alloy iron is discussed. Microphotographs are given of various structures found and a number of examples of heterogeneity quoted. The dangers of failure arising from the use of these very hard and sensitive rolls are stressed. A summary of the economic factors to be taken into account in their use and of the precautions to be taken in machining them is given.—J. H. E. J.

Precision Castings. B. Vécsey. (Öntöde, 1950, vol. 1, May, pp. 109–112; June, pp. 121–125: Bányászati és Kohászati Lapok, 1950, vol. 5, May–June). [In Hungarian]. A comprehensive account of precision casting by the lost-wax process is given.—E. G.

Tractor Foundry Employs Efficient Scheduling Methods. F. W. Shipley. (Foundry, 1950, vol. 78, Feb., pp. 86–93, 209, 210). Having described in considerable detail the equipment and production units at the foundry of the Caterpillar Tractor Co. where castings from ½ to 3400 lb. in weight are produced in numbers ranging from 1 to 15,000 per month, the author gives particulars of the machine schedules, production follow-up sheets, and other means employed to spread the load over the different units and to control supplies of materials and delivery times of the products.—R. A. R.

Handling Materials in Metal Pouring. R. H. Herrmann. (Foundry, 1950, vol. 78, Feb., pp. 79–83). A number of conveyor systems in foundries for molten metal ladles and moulds are described and illustrated.—R. A. R.

Modernization Trends in the Small Foundry. L. B. Knight. (Canadian Metals, 1950, vol. 13, Feb., pp. 26–29). Recommendations are made on the modernization of foundries, and three examples, two of small iron foundries, and one of a brass foundry, are described.—R. A. R.

Mechanization of Foundries. A. Küstel. (Bányászati és Kohászati Lapok, 1950, vol. 5, Feb.–Mar., pp. 215–220). [In Hungarian]. The problems of the mechanization of foundries in Hungary are reviewed. Better methods of dust control are required and it is mentioned that in Sweden water, which is atomized by compressed air, is supplied. If these atomizers are placed about 2–3 m. high, a fine cloud is produced which moistens the dust particles; the water evaporates before it reaches the head level of the operators, thus avoiding any unpleasant sensation on the skin. The need of having sufficient skilled personnel for servicing mechanized equipment and for the availability of sufficient suitable spare parts is emphasized.—E. G.

Testing the Metal or Testing the Casting. E. O. Lissel. (Institute of British Foundrymen, 47th Annual Meeting, 1950, Paper No. 976). A brief survey is made of the problem of relating the testing and specifying of grey cast iron and grey iron castings. Experimental data show that a reliable relationship between test bar and casting properties is only obtained with castings of very simple shape. There is a considerable spread in the strengths of similar sections of more complicated castings. A comparison of British, American, German, and Swedish specifications for cast iron shows that the first three are quite similar, and that they are intended to be a yardstick for both inspector and engineer, whilst Swedish specifications are drafted for production-control purposes only. The author concludes that: (1) The tensile test can be accepted for production control; (2) tensile tests on very small bars are apt to be erratic and should be avoided; (3) separately cast test bars are to be preferred to cast-on bars; (4) separately cast bars should be cast under standardized conditions; (5) the relationship between iron quality and casting properties should be studied statistically, and this correlation should be recorded in a 'Cast-Iron Data Book' and should not be included in specifications.—R. A. R.

The Theory of the Gassing and Degassing of Molten Metal Baths. W. Geller. (Zeitschrift für Metallkunde, 1950, vol. 41, Apr., pp. 124–127). Relationships are established for the gassing and degassing of metals with a blower of finite size, or an infinite number of small blowers, between the quantity of the purging gas and the gas content of the metal bath. These relationships are valid provided that either the gas content of the bath is proportional to the partial pressure of the gas in the gas phase or to the square root of the partial pressure.—R. A. R.

Solidification of Molten Metal. N. F. Hindle. (Foundry, 1950, vol. 78, Feb., pp. 97, 222–225). The mechanism of the solidification of molten metal is explained and its effect on the properties and design of castings is discussed. There are at least three forces tending to bring metal from the riser into voids created by the shrinkage which occurs during solidification. The first is the vacuum created by the shrinkage, the second is the weight of the column of liquid metal, and the third is the atmospheric pressure. Where two sections cross and are filleted at the junction, the cross-sectional area is much greater than that of the individual members. To reduce this increase in section size, crossing members should be staggered where possible. The use of exceptionally large fillets to increase the section modulus may defeat its own purpose.—R. A. R.

Solidification of Steel Castings and Segregation. M. Guédras. (Métallurgie, 1950, vol. 82, Mar., pp. 181–184; Apr., pp. 255–256). In a previous part the author dealt with contraction as the cause of piping. The present parts are concerned with segregation in relation to the formation of pipe. Starting with the formation of simple octahedral crystals, the crystallization of steel is examined.

The formation of a dendrite in a solid solution implies a gradual segregation of the low-melting-point constituent. The portion which solidifies last is the richest in the constituent. Diffusion which tends to make the dendritic segregation chemically homogeneous is rarely ever complete, and thus the dendritic structure can be shown by etching. Lack of evidence of a dendritic structure would indicate a chemically pure metal or a solid solution where diffusion had caused the dendritic segregation to disappear. The work of Stead on the effect of phosphorus in eliminating carbon from the interstices and concentrating it in the axes, is reviewed. Finally, the change points in the iron–carbon diagram are discussed.—R. S.

Evaluating Casting Finishes. H. H. Fairfield and J. MacConachie. (American Foundryman, 1950, vol. 17, Feb., pp. 47–48). Methods of rating the surface finish of castings are discussed, and a method of presenting a roughness value from a number of profile readings obtained with a needle-tipped dial indicator is presented.—R. A. R.

Planning Foundry Preventative Maintenance. T. F. Butler. (American Foundryman, 1950, vol. 17, Mar., pp. 47–49). Recommendations are made on maintenance arrangements in a foundry.—R. A. R.

Economy Plus from Vacuum Cleaning in Foundries. J. W. Gaffney. (American Foundryman, 1950, vol. 17, Apr., pp. 141–143). The advantages gained by an American foundry which installed vacuum cleaning in place of compressed-air cleaning are discussed. The equipment proper consists of a multi-stage centrifugal-type vacuum producer directly connected to a 30-h.p., 3450-r.p.m. motor and a 48 × 96-in. dust separator housing 30 filter bags in the upper part and a cone hopper in the lower part. Six operators can work simultaneously, each using a 50-ft. length of 1½-in. hose with a suitable nozzle. These hoses can be connected to coupling points on the fixed service pipes running from the vacuum plant along two foundry buildings. Vacuum cleaning of moulds and cores has greatly reduced sand inclusions in casting surfaces. Health conditions in the foundry are improved and there has been a marked reduction in the number of eye injuries.—R. A. R.

Time and Motion Studies in Modern Foundries. D. Iturrioz. (Metalurgia y Electricidad, 1950, vol. 14, Feb., pp. 21–23; Mar., pp. 24–27). [In Spanish]. The author discusses, in general terms, the conceptions of time and motion study, and systems of payment, giving examples relating to the flow of raw materials in a grey-iron foundry.—R. S.

Scientific Foundry Management and the Rôle of the Laboratory. A. Guédras. (Métallurgie, 1950, vol. 82, June, pp. 467–471). Lack of laboratory facilities in the past has been one of the causes of the slow pace of development of the foundry industry. The author presents a scheme for the rational organization of foundry management and discusses the line of responsibility through the order, costing, and production departments. Some general aspects of foundry research and testing laboratories are surveyed.—R. S.

HEATING FURNACES AND SOAKING PITS

Fuel Economy by Gas-Firing a Slab Heating Furnace. (Gas Heat in Industry, 1950, vol. 13, July, pp. 315–317). A description is given of the gas-firing installation which was installed when converting and improving a hand-fired coal furnace with a hearth 21 ft. by 10 ft. for heating slabs. Three air-blast burners with 1¼-in. orifices were fitted in each of the side walls. The maximum hourly gas consumption recorded was 1600 cu. ft.; the fan had a rated output of 200 cu. ft./min. at a pressure of 16 to 18 in. water gauge. The average gas consumption over four days was 6·3 cu. ft./lb. of metal, heating a charge of about 28,000 lb. of slabs and sheets.—R. A. R.

Design and Performance of Large Rotary Furnaces. A. F. Kritscher. (Iron and Steel Engineer, 1950, vol. 27, Feb., pp. 51–56). The advantages of rotary reheating furnaces over other types used in the seamless tube industry are discussed. The author then considers the fundamentals of design and operating conditions. A number of existing furnaces are described in detail. Examples are given of a rotary furnace working on high tonnages under steady conditions and of another giving equally good service with conditions intermittent and variable. Information based on many years' operating experience is given and tests carried out at Gary and Gambrinius Works are described. A number of heating curves are also given and their behaviour discussed.—M. D. J. B.

Rapid Responding Devices Control High-Speed Reheating of Seamless Steel Tubes. H. W. Cox. (Steel, 1950, vol. 126, Jan. 16, pp. 64–66, 68). At the Gary plant of the National Tube Co. the reheating of seamless tubes before final sizing is carried out by high-gradient heating in a line of thirteen furnaces. Control of the high heat input of 3 to 45 million B.Th.U./cu. ft./hr. is obtained by thermopiles of chromel–constantan thermocouples operating throttle valves in the premixed air/gas supply manifolds. Tubes moving through

the furnaces at 150 ft./min. can have their exit temperature controlled within ± 20° F. at temperatures up to 1800° F. Additional high-limit automatic control of temperature is provided to protect the tubes and furnaces.—A. M. F.

High-Temperature Combustion-Heated Furnaces. M. W. Thring. (Journal of the Institute of Fuel, 1950, vol. 23, July, pp. 178–188). An attempt is made to decide how far the thermal efficiency of industrial furnaces could be improved by application of existing fundamental knowledge, and in what directions more fundamental knowledge is needed. Existing knowledge can contribute to the achievement of rapid combustion, high rates of heat transfer to the charge and low rates to the outside atmosphere, particularly as regards control of the combustion-gas composition, the use of models to find out how to improve mixing and so shorten flames, and the more extended use of the counter-flow heating system. More knowledge is required on the emissivity of luminous flames, general conditions of mixing, and the effect of recycling combustion gases.—R. A. R.

A New Electric High-Temperature Furnace. (Iron and Coal Trades Review, 1950, vol. 160, Mar. 3, pp. 505–506, 508). An illustrated account is given of the EFCO-Olivotto high-temperature electric furnace which has a resistor consisting of a bath of molten glass. This furnace can be used for heating metals up to 1500° C. for purposes such as forging. The principle involved is the radiation of heat emitted from a bath of molten glass reflected from the roof arch on to the metal to be heated. It is claimed that oxidation is avoided, the electrodes have a long life, and the molten glass can be easily drained off when the furnace is not in use. Consistent results are attributed to temperature control and uniform heating. Power consumption, based on 18 months' continuous working, is under 500 kWh./ton.—J. C. R.

Radio Frequency Heating. E. T. Norris. (New Zealand Engineering, 1950, vol. 5, Feb. 15, pp. 138–140). The principles of induction heating and dielectric heating are explained and equipment for applying these forms of energy are described with notes on the advantages of the processes. R. A. R.

Induction Heating. J. Vazquez White. (Anales de Mecanica y Electricidad, 1950, vol. 26, Mar.–Apr., pp. 91–104). [In Spanish]. The author continues his article (*see* Journ. I. and S.I., 1949, vol. 163, Dec., p. 460) with a short résumé of the different types of coil used for hardening and indicates the methods used for reheating for pressing and forging, concluding with a description of the processes of high-frequency welding.—R. S.

Soaking Pits. H. Southern. (Iron and Coal Trades Review, 1950, vol. 160, Apr. 14, pp. 899–908). Developments in the design of soaking pits from the first square-section Gjers pit to modern regenerative pits are reviewed. A short comparison is made between the economics of using the following fuels: Blast-furnace gas, coke-oven gas, mixed gas, producer gas, and fuel oil.—R. A. R.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Thermodynamics of Surface Impregnation Processes. G. M. Willis. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept 15, 1950). The chemical potentials of elements can be used as a quantitative measure of their tendency to enter a metal from another phase. The chemical potentials of carbon in steels and in some gas mixtures as a function of carbon content are calculated and used to illustrate the relations involved in carburizing. The chemical potentials of nitrogen in the metal and gas phases occurring in nitriding are shown, and the effect of alloying elements which form stable nitrides is discussed briefly.

New Interstitial Alloy Phases Relating to the Surface Hardening of Steel. K. H. Jack. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept. 15, 1950). X-ray structural investigations of the iron–carbon, iron–nitrogen, and iron–carbon–nitrogen systems provide direct evidence for the existence of previously unknown or unconfirmed interstitial alloys of iron. The occurrence of these new phases and their transformations are of importance in the surface hardening of steel by the well-known commercial processes of carburizing, nitriding, and carbonitriding.

Liquid Carburizing. D. A. Colwell. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept. 15, 1950). The reactions involved in liquid carburizing result apparently in the formation of nitrogen and carbon from reactions involving the production of cyanate and/or cyanamide radicles. Accelerated baths aim at preventing the formation of free nitrogen by these reactions without inhibiting the production of atomic carbon.

The Mechanisms of Diffusion. P. J. Fensham. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept. 15, 1950). Several possible mechanisms for diffusion are discussed in terms of the atomic arrangement in solids. Theoretical and experimental evidence is presented which indicates that diffusion in solids may occur by means of the vacancies or lattice defects existing in solid crystals.

The Kinetics of Decomposition of Gases at Metal Surfaces. M. F. R. Mulcahy. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept. 15, 1950). The theory of the kinetics of decomposition reactions at metal surfaces is reviewed. The results of published experiments on the rate of decomposition of carbon from methane and of nitrogen from ammonia are described briefly. Some general observations are made on the relative rates of decomposition of the gas at the surface and subsequent diffusion of the product in the carburizing and nitriding processes.

Diffusion Phenomena in Metals. V. Sedláček. (Hutnické Listy, 1950, vol. 5, July, pp. 277–285). [In Czech]. The theory of diffusion phenomena in metals is explained. Formulæ for calculating the depth of the diffused layer and the relation of the diffusion coefficient to the temperature are given. The author classifies diffusion into four categories, namely, the Schottky, Frenkel, and the place-exchange and channel types of diffusion, and discusses these from the point of view of the internal structure of the material. Analysis of the equations enables conclusions to be drawn on the influence of pressure on the diffusion coefficient. The author also deals with practical applications of the diffusion theory, *e.g.*, nitriding and case-hardening.—E.G.

The Influence of Zinc in the Welding and Heat Treatment of Mark E Ya 1 T Stainless Steel. F. E. Tretyakov. (Avtogennoe Delo, 1949, No. 12, p. 12). [In Russian]. The frequent formation of cracks during the heat-treatment of welded articles made from a chromium–nickel steel was found to be attributable to the presence of thin films of zinc. Careful removal of the zinc with hydrochloric acid after degreasing prevented cracking.—S. K.

Determination of the Quality of Heat Treatment of Steel by an Electromagnetic Circuit and a Cathode-Ray Oscillograph. A. Pokorný. (Hutnické Listy, 1950, vol. 5, May, pp. 185–196). [In Czech]. The author has studied the possibility of using differences in the shape of hysteresis loops for drawing conclusions on the quality and heat-treatment of steel parts. Tool and high-speed steels have characteristic hysteresis loops which vary according to the quality and heat-treatment of the steel. The apparatus consists of a step-down transformer feeding the primary of the test transformer in the secondary of which a hole is provided for inserting the specimens. The output of the secondary winding is fed into an amplifying circuit which feeds the amplified voltage into a cathode-ray oscillograph. It was found that there is an optimum ratio of the primary to the secondary windings for which the shape of the loops is most favourable for observation. Twenty-six different steels after various heat-treatments were tested and the results are shown on 180 oscillograms. This method is particularly suitable for comparing samples of parts with a standard and for sorting out differently heat-treated parts of the same material, or parts made of different materials.—E. G.

Composition of Atmospheres Inert to Heated Carbon Steel. R. W. Gurry. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1950, vol. 188, pp. 671–687; Journal of Metals, 1950, Apr.). A series of charts is presented showing the composition of all gas mixtures of the elements carbon, hydrogen, oxygen, and nitrogen which, at temperatures ranging from 1000° to 1800° F., are in equilibrium with: (1) Austenite of various carbon contents, (2) iron and iron carbide, (3) graphite, and (4) iron and its oxide. The method of calculation and construction of the diagrams

is described, and from the charts it is possible to determine, from a room-temperature analysis of the furnace gas in question, the effect of the gas upon the steel at furnace temperature, thus providing a guide as to the resulting carbon content and the possibility of oxidation or carburization. It is emphasized that the charts are applicable only to carbon steels, except when inferences may be derived for alloy steels on the basis of carbon activity.—G. F.

Safety Procedures for Protection against Flammable Atmosphere Hazards of Special Atmosphere Furnaces. J. B. Smith. (Industrial Heating, 1950, vol. 17, Apr., pp. 592–600; May, pp. 818–824). The explosion hazards of heat-treating furnaces which utilize inflammable atmospheres are discussed. The procedure for avoiding explosive mixtures, where inert-gas purging cannot be carried out is presented in the first part, which also deals with explosion hazards in the atmosphere generators. In the second part, the safety procedure is given for cases where explosive mixtures are unavoidable because it is necessary to turn on or shut off the special atmosphere while the furnace is cold and inert-gas purging is not practical. The paper also outlines the procedure for protection against an interruption in the flow of the special atmosphere.—J. A. L.

Profitably Operating the Small Commercial Heat Treating Plant. O. Rutledge. (Industrial Heating, 1950, vol. 17, May, pp. 804–808, 922–928). A description is given of two small heat-treating plants designed to be adaptable to many classes and quantities of work. The factors for successful operation of such plants are discussed.—J. A. L.

Heat Treatment Plant in the Needle Industry. (Wire Industry, 1950, vol. 17, Aug. pp. 659–660). Guillaume & Sons, Ltd. of Alcester, needle makers, have recently installed two Birlec shaker-hearth conveyor furnaces. One of these, a 20-kW. hardening furnace, heats up to 50 lb. of small needles per hour. The shaker mechanism is air operated and the nickel–chromium alloy hearth plate is suitably grooved to make the needles travel lengthwise; they fall vertically into the quench tank, thereby minimizing distortion. A Birlec endothermic atmosphere generator, producing up to 250 cu. ft. of atmosphere gas per hour from town's gas, provides the non-decarburizing atmosphere in the furnace chamber for bright finish of the needles. The 8-kW. tempering furnace operates in the range 250–300° C. The temperature is controlled by an expansion-type regulator. Air circulation is provided by fan mounted in the heating chamber. The hearth plate is of mild steel and is not grooved. This installation occupies little space, the heat loss is said to be very low and, most important of all, the production is continuous. Further increase in output is expected by mechanizing the loading and unloading arrangement.—J. G. W.

Steering Parts Heat Treated Continuously at Nash Motors. (Industrial Heating, 1950, vol. 17, July, pp. 1144–1148) The heat-treatment of small motor-car parts in a furnace installation designed and built by Surface Combustion Corp. at Nash Motors, a Division of Nash Kelvinator Co., Kenosha, Wis. is surveyed. The furnaces are described and their operating data given. Particulars of the oil-quenching process and the tempering furnace are also given.—J. A. L.

Heat Treating Bolts Quickly and Efficiently at Oldsmobile. (Industrial Heating, 1950, vol. 17, June, pp. 964–970). A continuous furnace installation at Oldsmobile Division, General Motors Corp., Lansing, Mich., designed to heat-treat 1250 lb./hr. of cylinder bolts, is described. The bolts pass through a hardening furnace, oil quench, cleaning machine, and tempering furnace cycle in 91 min.—J. A. L.

Automatic Heat Treatment of Crankshafts at Oldsmobile Division. (Industrial Heating, 1950, vol. 17, Aug., pp. 1324–1332). A description is given of three continuous production lines for the automatic heat-treatment of crankshafts at the Oldsmobile Division, General Motors Corp., Lansing, Michigan. Details of the hardening furnaces, quenching mechanisms, tempering furnaces, and unloaders are given. The crankshafts are treated at the rate of 300/hr.—J. A. L.

Heat Treatment of Alloy Steels. C. E. McDermott. (Industrial Heating, 1950, vol. 17, May, pp. 790–798; June, pp. 980–986). In the first part of this paper definitions and explanations of heat-treating terms are given and the metallurgical background is discussed. This is continued in the second part where some of the advantages and disadvantages of the various heat-treating processes are dealt with.—J. A. L.

Heat Treating Shakeproof Fastenings. J. Wallerius. (Industrial Heating, 1950, vol. 17, May, pp. 810–816). Furnace systems for heat-treatment of metal fastenings at the Elgin, Illinois, plant of Shakeproof Inc., a Division of Illinois Tool Works are described. Various heat-treatments are listed and the processing of a particular product is dealt with in detail.—J. A. L.

Controlled Heat Treatment of Clock Springs. (Industrial Heating, 1950, vol. 17, Apr., pp. 608–612). An account is given of an age-hardening process for hairsprings for automobile electric clocks at Borg Products Division of George Borg Corp., Delavan, Wis. The manufacture of the hairsprings is briefly described and details of the tube-type electric furnace for the heat-treatment are given. The springs are age-hardened in a hydrogen atmosphere. Particular care is taken over the temperature recording and control of the process.—J. A. L.

Heat Treating Stainless Steel. L. F. Spencer. (Iron Age, 1950, vol. 165, May 11, pp. 65–69; May 18, pp. 86–89). Characteristics of stainless steels in the American Iron and Steel Institute range are described and the heat-treatment procedures for austenitic, martensitic, and ferritic compositions are outlined. Types of furnace equipment are discussed and suitable pickling procedures detailed.—A. M. F.

Commercial Service Offered by Cook Heat Treating Corporation. (Industrial Heating, 1950, vol. 17, Aug., pp. 1360–1366, 1459–1472). This is a description of the heating plant of the Cook Heat Treating Corporation, Los Angeles. Among the pieces of equipment described are the gas-fired batch tempering furnaces, pit-type electric recirculating furnaces, liquid carburizing and cyanide pots, a nitriding furnace, nitrate salt tempering baths, a continuous gas-fired normalizing furnace, electric salt-bath furnaces, and a vapour blast liquid honing machine.—J. A. L.

Oxy-Acetylene Flame-Hardening in Commercial Heat Treatment. J. T. Howat. (Industrial Heating, 1950, vol. 17, Apr., pp. 624–632, 696–702). The development of the oxy-acetylene flame-hardening process is given. A survey of flame-hardening applications is made which includes treatments to prevent machinery failures, methods of meeting machinery service conditions, choice of flame-hardening processes, applications of flame-hardening equipment, choice of fuel, characteristics of acetylene, fuel costs, controllability of flame-hardening, and physical properties obtained in the hardened parts.—J. A. L.

Thin Metal Parts Successfully Heated by Induction. J. F. Libsch and A. Vescuso. (Wire and Wire Products, 1950, vol. 25, June, pp. 498–499, 519–521). The advantages of induction heating for small wire and metal parts lie primarily in the absence of distortion. Difficulties are, however, encountered with wires below 0·037 in. in dia., because neither prolonged heating nor increased power will increase the temperature beyond a certain value. It is possible to increase the temperature by increasing the frequency, but a wide variation of frequency is required to accommodate a small change in wire diameter. The authors have developed a technique for heating such small parts, using a standard commercial converter operating at 500 kilocycles or less. The method consists of interposing a metal barrier between the part to be heated and the inductor coil; this barrier is so designed as to avoid shielding the magnetic flux from the work piece, and being itself heated acts as a radiator which cuts down heat loss from the work piece by radiation and convection. The barrier consists of a cylinder with a longitudinal slot $\frac{1}{16}$ to $\frac{1}{8}$ in. wide along its entire length, which is electrically insulated from the heating coil. In normal operation the cylinder is maintained at a temperature higher than that required for the work piece, which heats rapidly by induction to a temperature determined by its ability to absorb induced energy, and then by radiation from the metal cylinder to the desired temperature. Usually the length of the heating cycle may be used to control the temperature of the work piece, but in continuous heating of wire a safeguard is needed against overheating caused by some mechanical breakdown in the continuous process. This is afforded by selecting a suitable thickness for the radiator cylinder which controls its maximum temperature.—J. G. W.

The Development of High-Frequency Hardening Methods. E. Partiot. (Métallurgie, 1950, vol. 82, Apr., pp. 267–271).

High-frequency inductors for heating the surfaces of metals are described. The advantages of high-frequency treatment are : Concentration of energy is limited to a thin surface layer ; facility for partial or selective hardening ; elimination of the delicate operation of case-hardening ; no protection required ; the surface of parts which have been hardened throughout can be further hardened without having recourse to expensive special steels (surface hardening does not affect the strength of the core) ; no deformation ; considerable improvement of micrographic texture of the hardened layer ; absence of surface decarburization and practically no oxidation ; and possibility of selective hardening of difficult shapes. Some limitations of high-frequency hardening such as cost of equipment and necessity to bear in mind the lesser deformations of certain parts, are cited.

Some applications, including locomotive axles, cylinders, gear teeth, hubs, and crankshafts, are described and illustrated.—R. S.

Trouble Shooting in Tool Hardening. R. Stewart. (Canadian Metals, 1950, vol. 13, Mar., pp. 10–13, 50, 51, 47). Causes of tool failures, methods of tracing them, and suitable remedies are described. Wrong quenching, under- or overheating are traced by Rockwell hardness tests, and fracture examination is shown to reveal causes of failures. Notched tool failures are discussed. Etching is suggested for tracing seams, cracks, pipe segregations, and dendritic patterns. Use of the Shepard 'P–F' method of grain-size comparison is described as a means of tracing bad quenching. Soft spots and heat-treatment defects are discussed.—E. C.

Influence of the Tempering Time on the Hardness and Dimensional Stability of Steel. L. Jeníček and V. Dlouhý. (Hutnické Listy, 1950, vol. 5, Apr., pp. 149–154). [In Czech]. On the basis of published data and the results of their own experimental work the authors conclude that optimum hardness and dimensional stability after quenching can be obtained by a suitable combination of tempering temperature and tempering time, and that tempering for a long time at a low temperature is better than a short time at a high temperature in order to obtain maximum hardness and dimensional stability. It appears, however, that short-time tempering at a high temperature in salt baths does affect the equalization of the mechanical properties of the surface and the core of the heat-treated part.—E. G.

FORGING, STAMPING, DRAWING, AND PRESSING

Improvements in the Production of Crankshafts for Heavy Reciprocating Engines. F. W. Nierhaus. (Stahl und Eisen, 1950, vol. 70, Apr. 27, pp. 372–375). Heavy crankshafts must be built up by shrinking webs on to shafts or, preferably, by shrinking on cranks machined from forged blocks. Even the latter method is unsatisfactory because the fibres of the forging do not follow the shape of the crank or because the crank still contains the original pipe or segregation zone of the casting from which the block was forged. These shortcomings are avoided by the ring-forging process, in which two cranks are made by dividing a flattened forged ring, the unsound portions of the original block having been previously removed. During the past 15 years some 300 such crankshafts (approximately 1000 individual cranks) have been in service in diesel and mill-driving engines, compressors, and heavy gas engines without a single complaint.—J. P.

Quality Problems in the Production of Forgings. L. Németh. (Bányászati és Kohászati Lapok, 1950, vol. 5, Aug., pp. 478–489). [In Hungarian]. The author discusses the technical problems relating to the production of forgings with particular reference to conditions in Hungary where they are produced in pieces up to 28 tons. Rejects due to surface cracks amount to 20–40% of the total rejects. The manufacture of turbine rotors, steel tyres, and bicycle forgings is discussed.—E. G.

Preliminary Forging of Certain Special Steels before Rolling. L. Faure. (Société Française de Métallurgie: Revue de Métallurgie, Mémoires, 1950, vol. 47, July, pp. 487–510). Unless special rolling equipment is available, as at the August Thyssen works, Hamborn, preliminary forging is the best treatment for special steels which are (*a*) weak at high temperatures owing to a coarse crystalline structure (*e.g.*, 18/8 stainless steels) or to the segregation of carbides (*e.g.*, high-chromium steels), (*b*) too strong at high temperatures, or (*c*) too large in section for the available rolling equipment. The hammer and press-forging are discussed. Special constructional steels and high-carbon (>1·2%) steels with less than 2% of alloying elements are press-forged. Hammer forging is used for steels with primary carbides, 18/8 steels, heat-resisting austenitic steels, and high-nickel steels.—A. G.

The Business of Cold Heading. K. J. Sorace. (Wire and Wire Products, 1950, vol. 25, June, pp. 500–501, 517). Some of the factors encountered in the making of screws of various designs are enumerated. It was found, for instance, that wire of lower hardness and tensile strength gave better tool life. In another case, when an alloy steel was substituted for the material used normally in the production of 0·615 in. dia. by 2 in. long headed pins, the pins were 0·040 in. too short.

J. G. W.

Complex Steel Parts Produced by Hot Extrusion Process. J. Sejournet. (Materials and Methods, 1950, vol. 31, Mar., pp. 56–58). The French company, le Comptoir Industriel d'Etirage et Profilage de Métaux (C.I.E.), have developed, patented, and begun operating a process for the hot extrusion of steel. This has been shown to be feasible, and without technical surprises even for highly alloyed stainless, creep-resisting, and high-speed steels. The success of the process is due to the solution of the problems of lubrication and thermal insulation of the dies and holder. No details are given. The many advantages of hot extrusion, (*e.g.*, improved mechanical properties, less waste, lower costs, etc.), are briefly reviewed, and a few examples of the intricate shapes, and some applications of extruded steel products, are illustrated and described.—P. M. C.

Study of the Plastic Deformation of Metals by Drawing : Shape of Die, Factors Affecting Mechanical Characteristics of Product. J. Navarro. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Aug., pp. 601–613). Simple cold-drawing tests (no back tension) were carried out using a die with a truncated internal surface. Materials used for dies and the defects caused by a faulty profile are described. The effect of cone angle, size of die hole, elongation imposed, and speed of drawing on the drawing characteristics and on the properties of the finished wire (both as-worked and as-annealed) is determined. High drawing speeds may affect the cohesion of the metal but are possible with intermediate annealing. Large reductions in section give a more uniform structure to the wire. An appendix on the relations governing wire drawing is given.—A. G.

British Diamond Dies—An Historical Survey. (Wire Industry, 1950, vol. 17, June, pp. 503–505). The author summarizes the report on diamond dies prepared by the Technical Committee of the British Diamond Die Federation. As a common unit to measure die performance, the logarithm of the length of wire drawn per 0·0001 in. enlargement of the die during service was adopted. Whilst there may be small differences in the quality of dies obtained from different manufacturers, these are much smaller than the differences in performance arising from the conditions under which the dies are used.—R. A. R.

Profile of Wire-Drawing Dies. J. G. Wistreich. (Iron and Coal Trades Review, 1950, vol. 160, Mar. 10, pp. 561–564). An account is given of some of the applications of the wire-drawing die profilometer, developed by the British Iron and Steel Research Association and described in Journ. I. and S.I., 1950, vol. 164, Jan., pp. 63–66. Problems being investigated include the improvement of the precision of the die-shaping process and the mechanism of the wear of dies.

J. C. R.

The Baking of Lime Coatings on Wire. (Wire Industry, 1950, vol. 17, Mar., pp. 257–258). An illustrated description is given of a 'flash baker' for the rapid baking of the lime coating on coils of wire. The furnace is of insulating brick, about 11 ft. 6 in. long and 7 ft. deep with 4 ft. below and 3 ft. above ground level. Its top consists of two asbestos-lined swing doors. Heating is by forced convection from the products of combustion of town gas diluted with fresh air. Baking is completed in 10 to 30 min. A throughput of 72 tons/24 hr. can be obtained with a consumption of 40,000 cu. ft. of gas of 180 therms/cu. ft.—R. A. R.

Modern Wire Nail Manufacture. (Wire Industry, 1950, vol. 17, Apr., pp. 334–341). **Nail Production.** (British Engineering, 1950, vol. 33, July, pp. 80–85). An illustrated description is

given of the reorganized nail works of Rylands Brothers, Warrington. Great attention was paid to the layout and organization. The heaviest possible coils of wire are used so as to obtain long runs on the machines; accordingly standardized coil weights of 18–20 cwt. for 8 gauge and thicker, 7–10 cwt. for 8 to 16 gauge, and 2–4 cwt. for 16 to 20 gauge have been introduced. The wire is drawn on detachable strippers, and the coil on its stripper is conveyed to the nail department. A high degree of mechanization has been achieved, particularly as regards the polishing plant; details of this and other time and labour saving devices are given. R. A. R.

The Hot Rolling and Cold Drawing of Stainless Rods and Wire. J. K. Findley. (American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, Symposium Series vol. 3, 1949, pp. 16–22). The difficulties encountered in the rolling and drawing of stainless steel wire are discussed. Pickling of annealed stainless steel rod in molten caustic salts reduced the time formerly required in strong acid. Finer gauges of wire are annealed by passing each strand through a tube in which flows purified hydrogen or dry dissociated ammonia. It was difficult to draw wire through tungsten carbide dies at over 200 ft./min. without heavy machines with air-cooled drums, heavy water-cooled dies, and the very best lubricant.—R. A. R.

An Appraisal of Wire Products in Industry. W. F. Hodges. (American Institute of Mining and Metallurgical Engineers, Institute of Metals Division, Symposium Series vol. 3, 1949, pp. 1–5). The history and progress of the wire industry and some of the uses of wire are briefly reviewed.—R. A. R.

ROLLING-MILL PRACTICE

Plastic Deformation in the Rolling Process. B. L. Averbach. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1950, vol. 188, pp. 150–153; Journal of Metals, 1950, Jan.). An account is given of the distribution of the principal strains in a bar after a 20% rolling reduction, determined by radiographing a lead grid embedded in a cast tin bar. It is shown that axial and vertical principal strains are of similar magnitude and direction to those reported at the surface of a bar by other investigators; whilst the lateral principal strain changes from tension at the centre to compression midway between the centre and the outside in a section perpendicular to the roll axis.—G. F.

The Effect of Speed, Temperature, and Type of Roll on Spread and Elongation in the Hot Rolling Process. Z. Wusatowski and R. Wusatowski. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 2. pp. 111–122). [In Polish]. (Hutnické Listy, 1950, vol. 5, Oct., p. 417). [In Czech]. Calculations made according to Z. Wusatowski's formula (see Journ. I and S.I., 1950, vol. 165, Aug., p. 465). have shown that its accuracy can be improved. By statistical analysis of the results of his own experiments and some data found in the literature, corrections have been made which cover the effect of rolling speed, temperature, type of roll, and roll surfaces. These corrections enable the average error to be reduced by 43·6%.—V. G.

The Mill Motor after Forty-Five Years. S. S. Burns. (Iron and Steel Engineer, 1950, vol. 27, June, pp. 105–112). This paper describes the salient features of the new types of mill motor standardized by the Association of Iron and Steel Engineers in 1947. The heating and ventilation of the motors are discussed in detail. The internal air circulation of the totally enclosed mill motor is claimed to dissipate heat effectively. The features which make it possible to improve the commutating quality, to increase the overload commutating capacity, and reduce brush and commutator wear are discussed as well as insulating materials, armature coil and armature winding insulation, and the commutator and interpole and field coil insulation. The mechanical features described include bearings and bearing mounting, armatures, commutators, brush-holders, field coils, enclosures, and frames. M. D. J. B.

Couplings for Rolling Mill Drives. W. P. Schmitter. (Iron and Steel Engineer, 1950, vol. 27, Aug., pp. 71–79). The efficiency of torsional resilience in flexible couplings for alleviating the mass elastic system from the effects of disturbances is discussed. The general theory of shock reduction, and the capacity of couplings for internal work and arresting vibration are developed. Inflated gland couplings and other types of resilient couplings are reviewed and their application to continuous hot mills described. Shear pin protection, controlled torque stop for cycle peaks, and the influence of resilience on blooming mill loads are also discussed, and results are given of field tests carried out on couplings. M. D. J. B.

The Influence of Weight Tolerances on the Geometric Characteristics of Rolled Sections. A. Brayda. (Costruzioni Metalliche, 1949, vol. 1, May–June, pp. 25–26). The author shows how the theoretical tolerances of ± 4% and ± 6% by weight which are generally considered permissible may seriously influence the geometric characteristics, lengths, areas, moment of resistance and moment of inertia, of rolled sections. Fortunately, in practice, the rolling limits are considerably below the figures of 4% and 6% quoted, and the author suggests that these limits should therefore be brought down to the actual tolerances to which the majority of rolling mills work.—M. D. J. B.

Back-Up Rolls and Bearings. H. P. Lemm. (Stahl und Eisen, 1950, vol. 70, May 25, pp. 452–459). The development of rolling has led to the use of four-high mills in which the work rolls are supported by back-up rolls. This development has been favoured by the production of suitable rolls and bearings. Of the various types of back-up roll, the most important is the sleeved, and in particular the steel-sleeved, roll. Back-up rolls generally run in roller or oil-film bearings, seldom in bronze or plastic. There is a close connection between the dimensions of a back-up roll and its bearings, and information is given about the choice of size and type of roll and bearing for various loadings.—J. P.

Modern Rod-Rolling Mills and Their Roll-Neck Bearings. T. Dahl. (Stahl und Eisen, 1950, vol. 70, June 22, pp. 543–552). The advantages and disadvantages of open and continuous rod mills are described. The former involve less driving costs but more mill hands than the latter. The present state of development of both types is illustrated by a number of layout plans. Attempts to apply continuous working to open mills are reported. The bearings for the rapidly rotating rod-mill rolls are almost exclusively precision roller bearings, and the latest innovations are discussed.—J. P.

Roller Bearing Applications. J. A. Toth. (Iron and Steel Engineer, 1950, vol. 27, July, pp. 81–84). The importance of bearings in economical and effective mill operation is discussed. Whilst it is essential to obtain the correct type and size of bearings to ensure that these are not overloaded, it is equally important to ensure that bearings are given the most careful maintenance. The need for accurate assembly and good lubrication is stressed. If the actual loads do not exceed 50% of the design loads, the life of a bearing may be increased by ten years. The best types of oils and greases for bearing and housing lubrication are also discussed.—M. D. J. B.

Using Cast Iron and Mild Steel as a Material for Roll Bearings in Rolling Mills. J. Teindl. (Hutnické Listy, 1950, vol. 5, Mar., pp. 97–101). [In Czech]. Cast iron and mild steel bearings were used experimentally in roll stands at several works in Silesia to replace bronze bearings. The compositions of the cast iron and steel used and test data are reported. Drawings show the design of the bearings and stands. The bearing surfaces after use and their microstructures are also illustrated. These materials can be used in stands for hot-rolling thin strip, cast iron being suitable in the tops and sides of the bearings. Mild steel is applicable in stands with roll-neck diameters exceeding 600 mm. The type of stand and the lubricant have a great effect on the bearing life.—E. G.

Consideration in the Development of Roll Neck Oil Seals. E. W. Fisher. (Iron and Steel Engineer, 1950, vol. 27, May, pp. 92–96). The author describes the problem of oil seals which has become increasingly important with the advances made in high-speed mills and power lubrication. Various types of seal are considered and their uses and relative merits discussed. A theory and rules for the good design of oil seals are given.—M. D. J. B.

New Blooming, Bar and Billet Mills of Lorain Works. A. F. Eisel. (Iron and Steel Engineer, 1950, vol. 27, Aug., pp. 100–107). The new blooming, bar, and billet mills constituting one of the principal additions in the post-war improvement and development programme at the Lorain Works of the National Tube Co. are described. Brief details and layout drawings of the train of mills, soaking pits, and shearing equipment are

given. The unit comprises one 46 × 100 in. 2-high reversing blooming mill, one 38 × 96 in. 2-high reversing bar mill, one 6-stand continuous billet and bar mill, and finally one 4-stand continuous mill. The 6-stand continuous mill is designed to produce a wide variety of semi-finished products from 9 × 8 in. blooms. The mill is equipped to roll 4 × 4 in. billets, 5⅝ × 4 in., 7 × 4 in., 8 × 4 in., and 9 × 4 in. skelp slabs, and 4¾ in. and 5½ in. tube rounds.—M. D. J. B.

The New 46-in. Cogging Mill of La Société d'Ougrée-Marihaye. F. Sepersonne. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Oct., pp. 337–341). Details are given of the erection of a new 46-in. cogging mill at the works of Société d'Ougrée-Marihaye, Belgium. The mill was constructed in America and is fitted with the most modern equipment.

B. G. B.

Rail Slitting Mills. C. W. Barrett. (Iron and Steel Engineer, 1950, vol. 27, Aug., pp. 59–66). Slitting mills, which make use of old railway rails for re-shaping into a wide variety of small sections, are described. Although this type of mill has not developed much because the supply of scrap rails has diminished through better manufacturing methods giving greater rail life and also because of the possible metallurgical unsoundness of the re-rolled product, the author maintains that modernized rail-slitting mills can keep pace with the regular bar mills and produce a product that has a definite place in industry. Six rail-slitting-mill layouts are described and their relative merits discussed. Roll shapes and the range of finished product obtainable by this method of slitting and re-rolling old rails are examined.—M. D. J. B.

Pass Design of Angular Sections. R. E. Beynon. (Iron and Steel Engineer, 1950, vol. 27, June, pp. 53–74). An historical introduction to the rolling of angle sections is given. The author then describes the butterfly principle and gives a number of pass layouts which serve to illustrate the various types of butterfly angle pass design. The angularity of angle passes, the shape of leader passes, and the angle of finishing passes for unequal angles are considered. The rolling of small angles and bulb angles and the problem of angle reductions and the rolling of **Z** bars are discussed. The paper is illustrated with a large number of detail pass drawings.—M. D. J. B.

Sections with Parallel Flanges. J. Courthéoux. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Sept., pp. 669–677). American and European practices in the rolling of **H**-sections are compared. There are three methods in use; (*a*) Flat rolls as at Differdange (making sections up to 750 cm. deep); (*b*) biconical rolls, used in many American works; and (*c*) grooved rolls as at Hagondange, Hamborn. The relative advantages of these systems are discussed. In France a complete series of beam and channel sections is made with absolutely parallel internal and external flange faces and larger and thinner flanges. These are easy to rivet or bolt and also to cut or drill. A few of the many applications of such sections are given.—A. G.

The Rolling of Hollow Boring-Tool Steels. P. Grüner. (Stahl und Eisen, 1950, vol. 70, June 8, pp. 506–509). Steels for boring tools are rolled so as to possess the desired finished profile. They have a narrow axial hole for feeding cutting oils when in use. Programmes for hot-rolling square, hexagonal, oval, and winged profiles are described. The axial hole is obtained by boring centrally the original billet; the diameter of the hole is controlled and kept uniform and its surface is kept smooth by inserting a rod of steel (approximately 12% Mn, 1% C) which remains in position during all the rolling operations. The steel core has a much higher coefficient of thermal expansion than the tool steel and it is therefore easily withdrawn when the finished bar is cold.

J. P.

Quality Problems in the Rolling of Rails. A. Wojcik. (Hutnick, 1950, vol. 17, May–June, pp. 106–113). [In Polish]. The following factors affecting the quality of rails are surveyed: (1) The influence of rolling temperature on the grain size and quality of the surface of the rails. (2) The influence of the method of calibration on crystallization in the base of a rail. (3) The influence of the method of cooling. (4) The influence of cold straightening. The phenomena of ageing, methods of producing hardened rails, and the effect of the chemical composition and grain structure of the steel on wear and corrosion resistance are discussed.—V. G.

Electric Equipment for High Speed 2-Stand Temper Pass Mills. R. E. Marrs. (Iron and Steel Engineer, 1950, vol. 27, June, pp. 95–99). This paper describes the electric equipment most suitable for a typical 2-stand temper pass mill operating at a maximum speed of 3600 ft./min. The mechanical arrangement of the mill, the power requirements for temper rolling, and the acceleration and deceleration torque requirements are considered. Details are given of the armature circuits, the excitation and regulator circuits, the twin-drive motor load balance, and the operator's remote control equipment.—M. D. J. B.

Cold Rolling. M. Zdunkiewicz. (Przeglad Techniczny, 1950, June, pp. 292–297). [In Polish]. The influence of cold rolling on the structure of the rolled material is described, and an historical survey is made of the development of rolling equipment.—V. G.

Electrical Equipment for Rolling Cold Strip at 70 m.p.h. W. E. Miller. (Iron and Steel Engineer, 1950, vol. 27, Jan., pp. 119–126). The principal advances in cold rolling during the last 15 years are reviewed and the author describes the new Jones and Laughlin Steel Corp. 5-stand mill, the fastest in the world, capable of rolling tinplate at 6250 ft./min. The author describes the mill equipment, layout, mechanical arrangement, and ventilating system, main drive controls, mill speed control, and twin-drive regulating system which ensures that upper and lower rolls keep equal peripheral speeds. Reel tension control, circuit constants, screwdown equipment, and an X-ray thickness gauge are also described. The article is followed by ten references.—M. D. J. B.

The Cold Rolling of Steel Strip. L. Gascuel. (Métallurgie, 1950, vol. 82, Mar., pp. 199–203). A general survey is given of the processes involved in the manufacture of cold-rolled steel strip. Descaling methods are described. The effects of roll diameter and of friction in rolling are briefly indicated. Various types of cold-rolling mill are noted and illustrated diagrammatically. Methods of avoiding oxidation in annealing are outlined.—R. S.

Cold Rolled Strip. (Métallurgie, 1950, vol. 82, June, p. 465). The tendency of the steel-consuming industries to use more flat products is illustrated by figures for American sheet and strip deliveries. Flat products formed 17% in 1925, and 29% in 1947, of the total steel-product deliveries in the U.S.A. Comparable French data show how the percentage of cold-rolled strip has increased in relation to other products. Usual sizes and applications of cold-rolled strip are briefly reviewed and some general remarks are made on the advantages of this product.—R. S.

The Measurement of Surface Finish and Its Application to Problems in the Steel Industry. M. R. Hopkins. (British Iron and Steel Research Association, Jan., 1950). Descriptions are given of the Talysurf stylus instrument and the Guild Smoothness Meter for measuring surface roughness. The latter employs a photocell to measure the total reflected light and the diffusely scattered light when a small area of the surface is illuminated within a metal sphere a few inches in diameter painted matt white on the inside. The difference between the two intensities gives the light specularly reflected by the surface, the value obtained decreasing with increasing roughness of the surface. The stylus method does not require great skill to operate it. The photometric method is particularly suitable for the routine control of the surface quality of highly finished rolled sheet.—R. A. R.

Alan Wood Puts Hot Strip Mill in Operation. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 122–126). This article describes a new 30-in. continuous hot strip mill recently completed at the Alan Wood Steel Co. The mill is rated for a capacity of over 200,000 tons/year and is designed to produce hot-rolled strip 0·059 in. to 0·0746 in. thick up to 16 in. wide, and 0·1196 in. to 0·25 in. thick up to 25 in. wide. Details are given of the heating furnace, the roughing and finishing stands, and the motor room.—M. D. J. B.

Electric Controls As Used in Finishing Steel. R. W. Barnitz. (American Iron and Steel Institute, May, 1950, Preprint). Several applications of electronic control devices in rolling mills are briefly described. These include: (*a*) A side register control for an electrolytic tinning mill to shift the tension reel transversely to compensate for 'weaving' of the strip and thus ensure that the coil is wound with even edges; (*b*) a controller for a flash-butt welder when welding the trailing edge of one coil of strip to the leading edge of the next coil; (*c*) X-ray equipment for measuring the thickness of moving hot or cold rolled strip; and (*d*) a block speed

control when wire is drawn through a series of dies.—R. A. R.

Mill Rolls Salvaged by Stainless Facing. (Iron Age, 1950, vol. 165, May 18, p. 94). Sheet mill conveyor rolls subject to heavy wear by corrosion and abrasion have been successfully resurfaced with stainless steel weld metal, giving a substantially increased life.—A. M. F.

Developments in Coil Conveyor Equipment Design. L. O. Millard. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 99–103). The advantages of conveyors for the handling of coils of hot strip are greater safety, less risk of damage to the coils, and economy over other methods. The author discusses the relative merits of different types of conveyor designed for carrying coils on their sides and on end to suit production requirements. Coil dischargers and transfer units are also examined.—M. D. J. B.

Mill Tackle. M. S. Doshi. (Iron and Steel, 1950, vol. 23, Feb., pp. 39–45). The design of different tackle components comprising the cramp bar, guards, and guides for rolling mills is discussed. It is shown how, with the right kind of tackle, the quality and quantity of the rolled product can be improved and manual work eliminated. In the rolling of guide rounds the roll designer can facilitate the manufacture of tackle without sacrificing any fundamentals in roll-pass design. A standard procedure for designing precision tackle by projection drawings from the roll design is described.—R. A. R.

MACHINERY FOR IRON AND STEEL PLANT

Specification for Heavy Duty Electric Overhead Travelling Cranes for Use in Iron and Steel Works. (British Iron and Steel Research Association, May, 1950). This specification has been prepared by the Steelworks Cranes Sub-Committee of the Plant Engineering Division of B.I.S.R.A. In addition to covering the requirements of robustness and ease of maintenance, a major object has been to provide a means whereby the purchaser can obtain a crane which will give the performance he requires.—R. A. R.

A Magnetic, Reversing, Plugging Control for Crane Bridge Service. K. S. Kuka. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 104–106). The author stresses the need for liberally dimensioned motors and for adequate braking systems on steelworks cranes. Electrically operated series brakes should be given preference to hydraulic brakes. If this has not been generally accepted on modern bridge cranes it is owing to the tendency to get hook swing with series brakes. The paper studies a modified circuit giving controlled series brake operation.—M. D. J. B.

New Ten Ton Electric Luffing Cranes Installed at Newcastle Steel Works. (B.H.P. Review, 1950, vol. 27, Mar., pp. 8–9). Particulars are given of two 10-ton luffing cranes recently erected on the wharves of the Newcastle Steel Works (New South Wales). Each crane weighs about 190 tons and has two 100-h.p. motors for hoisting. An interesting feature is that the jib is raised or lowered by means of a crank and connecting rod on each side of the crane.—R. A. R.

Installation of Electric-Motor Control Gear. J. L. Watts. (Sheet Metal Industries, 1950, vol. 27, Jan., pp. 27–30, 34). Recommendations are made on circuits, switchgear, and safety devices for controlling electric motors.—R. A. R.

Determination of Size of Electrical Equipment. G. Scheer. (Iron and Steel Engineer, 1950, vol. 27, Apr., pp. 93–98). The author discusses the two criteria for determining the capacity of electrical equipment, namely, the ability to dissipate heat and the short-time ability to function under maximum load. Three simple curves are given : The first from which the ratio between the time that the normal load is imposed on the equipment and the root-mean-square value of the normal load can be read ; the second from which any load can be converted into its equivalent time of normal load ; the third from which a load changing at a constant rate can be converted to an equivalent load. A numerical example, based on these three curves, is worked out.

M. D. J. B.

Basic Patterns for Arrangement of Electric Power Systems for Steel Mills. H. J. Finison. (Transactions of the American Institute of Electrical Engineers, 1950, vol. 69, Part I, pp. 54–60). The supply and basic distribution systems for electric power in steelworks are discussed under the following headings : Steel mill installation problems, switchgear, system without current limiting reactors, short circuit level at loads, use of reactors to limit fault currents, synchronizing bus, system interconnections to synchronizing bus, choice of voltage, need for higher voltages, and expansion of existing systems.—R. A. R.

Network Calculator and Its Use in the Steel Plant. S. Ein. (Iron and Steel Engineer, 1950, vol. 27, Mar., pp. 53–59). The author describes a calculator for designing electrical networks and studies which can be performed on it, giving examples. Briefly, the network calculator provides the means for operating any electrical system in miniature, and is a combination of resistances, reactances, auto-transformers, and an alternator. These elements can be combined to represent a model of the actual system studied. The three types of work which the calculator can handle are examined, namely, short-circuit study, checking of voltage regulation, and checking the stability of generators. In each case examples are given showing the advantages which can be derived by the use of the equipment. These fall into one of three groups : (*a*) Confirming a correct solution, (*b*) revealing faults, and (*c*) pointing to a better solution. The author is of the opinion that a network calculator can be used with advantage in a steelworks and show considerable saving.

M. D. J. B.

Maintenance of Antifriction Bearings. J. M. Bruening. (Mechanical Engineering, 1950, vol. 72, Feb., pp. 142–143). Recommendations are made on the maintenance, fitting, removal, and cleaning of ball and roller bearings.—R. A. R.

Rational Selection of Bearings. B. T. Ruley. (Ingenieria e Industria, 1949, vol. 17, Dec., pp. 54–56, 122). [In Spanish]. Some useful definitions and standards are given for designing and specifying roller bearings.—R. S.

AISE Carbon Brush Standardization. H. Conover. (Iron and Steel Engineer, 1950, vol. 27, Feb., pp. 108–110). The author describes the recommendations put forward by a committee called to standardize mill motor brushes. A comprehensive table giving present and suggested carbon brush standards is included. The author stresses the fact that the adoption of these standards would result in considerable economy and much saving of orders.—M. D. J. B.

Equipment for Extracting Ingots from Their Molds. H. W. Ball. (Iron and Steel Engineer, 1949, vol. 26, Apr., pp. 116–121 : Association of Iron and Steel Engineers Yearly Proceedings, 1949, pp. 245–250). The design of ingot strippers is discussed, and illustrated descriptions are given of stripper cranes, electric and hydraulic stationary ingot strippers, horizontal hydraulic strippers, and an auxiliary stripping mechanism for big-end-up ingots with hot tops which supplements the standard overhead machine for big-end-down ingots.—R. A. R.

WELDING AND FLAME-CUTTING

The Results of the Conference on Automatic Submerged-Arc Welding, Held at Kiev on 3–6 October, 1947. (Avtogennoe Delo, 1948, No. 1, pp. 1–21). [In Russian]. In a review of progress made in the application of automatic submerged-arc welding, the steady growth since 1944 of the annual tonnage welded was indicated, and examples of the favourable results obtained by many industries through the adoption of this technique were given. Possible applications in bridge building, tube making, and metallization were considered together with methods of increasing the productivity of automatic welding operations. Special sections of the conference considered the following: Experiences with different fluxes; problems of plant design; rationalization of automatic welding techniques; and fundamental and operational research to provide a basis for desirable improvements.—S. K.

Deformations of Carbon and Alloy Steel Plates during Automatic Submerged Welding. V. M. Rybakov. (Avtogennoe Delo, 1948, No. 2, pp. 15–20). [In Russian]. An account is given of measurements of deformation carried out with a simple apparatus after cooling steel plates to which beading welds had been made along an edge using an automatic submerged A.C. arc process. The plates were rectangular, 500 mm. long, 110–140 mm. wide and 8–12 mm. thick, and had been subjected to tempering at 650–700°. The effect on the deformation of the following factors was investigated: Composition of the steel; strength of current; speed of welding; arc voltage; type of flux; angle of inclination of the electrode; type of electrode wire; and number of layers welded. The

results obtained are presented graphically, and it is concluded that deformations can be reduced by correct selection of conditions.—S. K.

Determination of the Conditions for Automatic Submerged-Arc Welding for Butt-Welding without Bevelled Edges. M. R. Shraerman. (Avtogennoe Delo, 1948, No. 3, pp. 10–15). [In Russian]. The requirements for a satisfactory square butt joint formed by one pass on each side are considered in terms of the thickness of the welded sheet, the thickness of the unmelted metal under the molten weld, the depths of the fusion of the base metal at the first and second passes, and the extent to which the first and second passes interlock. The relation of these factors to the conditions of welding are presented graphically. Nomograms are given for three different fluxes in which the following factors are related: Depth of fusion, thickness of sheets, arc voltage, strength of welding current, speed of welding, and thickness and width of the seam.—S. K.

Welding of Nuts to Pins in a Spot-Welding Apparatus. B. G. Filippov. (Avtogennoe Delo, 1948, No. 1, p. 27). [In Russian]. A brief description is given of a special electrode which has been found satisfactory for spot-welding nuts or discs to spindles without damage to the threads. This apparatus is simple to use and gives extremely strong welds. S. K.

The Technology of Butt-Welding Steel Rings of Large Diameter and of Large Cross-Section. V. I. Korovkin. (Avtogennoe Delo, 1948, No. 1, pp. 27–28). [In Russian]. Based on experiences with two types of welding machine, each of 200 kVA. but one with manually and the other with electrically actuated securing clamps, conditions for the butt-welding of two half-rings to form a ring are summarized. Both low-carbon and special steels were dealt with, the approximate cross sections being 75 × 60 mm. and 65 × 35 mm. respectively, and the approximate diameters 880 mm. and 1280 mm. respectively. For each of these information is given on the contact pressure, the extent of fusion, the distance between clamps, the welding time and the preparation of the contact surfaces, as well as on the electrical conditions. S. K.

Control of the Hardening Process of Structural Steel during Welding. N. N. Rykalin and L. A. Fridlyand. (Avtogennoe Delo, 1948, No. 2, pp. 3–11). [In Russian]. The influence of the thermal conditions during arc welding on the mechanical properties of the joint, and the interpretation of curves of the isothermal decomposition of austenite are considered. For choosing the conditions of welding required to obtain joints of given hardness, a method of calculation attributed to the Moscow Technical College is described. This is based on: (*a*) The relationship between the technical conditions of the welding process and the constructional parameters of the joint on the one hand, and the rate of cooling of the weld on the other; (*b*) the relationship between the hardness of a given steel and the rate of cooling in the upper subcritical interval. Different sets of equations are given for calculating the rate of cooling during the welding of sheets thicker or thinner than 5 mm., the values of the parameters for various conditions being tabulated or shown graphically. Two examples are worked, showing the calculation of rate of cooling for steel sheets 1·5 mm. thick welded with and without preheating respectively. The calculation of the hardness for various cooling rates is based on hardenability tests with Jominy specimens or on special tests in which beads are welded along plates under carefully controlled conditions. Nomograms are given for the calculation of cooling rates in these tests. Three examples are worked to show the calculation of the correct conditions for: (*a*) Butt-welding, using a manual arc process, steel 8 mm. thick containing 0·3% of carbon, 1·06% of manganese, 1·03% of silicon, 1·01% of chromium, and 0·26% of nickel to give a Vickers hardness of 300 in the weld area; (*b*) automatic butt-welding of the same steel, 5 mm. thick, to give the same hardness; (*c*) automatic welding under flux of a steel 16 mm. thick, containing 0·25% of carbon, 0·58% of manganese, 0·18% of silicon, and 2·8% of nickel to give a Vickers hardness of at least 250. Hardenability curves are given for a number of other American and Russian steels.—S. K.

Local Elastic and Plastic Deformations in the Process of Welding a Bead on a Plate. N. N. Prokhorov, N. V. Shiganov, and A. V. Mordvintseva. (Avtogennoe Delo, 1948, No. 2, pp. 12–15). [In Russian]. The results are graphically presented of experiments in which the deformation and strain were determined in plates which had been bead-welded along their edges. The plates were 10 mm. thick, and had lengths of 20, 40, 60, 80, 100, and 180 mm. It was found that for this type of process, increasing plate width up to a given limit increased the tendency to cold cracking through both increased deformation during cooling and quicker elastic-plastic deformation. The deformation was found to decrease with increasing temperature of welding when a second layer was welded on. Water cooling of the weld was found to decrease the residual strain, the maximum effect being obtained when the stream of water followed the arc so as to strike the metal at a temperature of 225–275°.—S. K.

Stand for the Assembly and Welding of the Side Framework of a Railway Wagon. N. I. Kazakov. (Avtogennoe Delo, 1948, No. 2, pp. 23–25). [In Russian]. The procedure for the assembly and welding of the sides of railway wagons and a special stand for holding the sides which measure approximately 2700 × 13,600 × 100 mm. are described. S. K.

Preparation of a Cutting Tool by Welding on the Cutting Edge with a Special Electrode. V. V. Danilevskii. (Avtogennoe Delo, 1948, No. 2, pp. 26–27). [In Russian]. In the procedure described a layer of the following composition is electrically welded on to the cutting tool: Carbon 1·0–1·15%; molybdenum 2·5–3·5%; chromium 4–5%; tungsten 5–6%; vanadium 2–3%; nickel 0·35%; manganese 0·45%; silicon 0·4%; phosphorus 0·03%; sulphur 0·03%. A low-carbon electrode 5 mm. thick is used, the alloying elements being obtained from the electrode coating which forms up to 40% of the total weight of the electrode and is applied in two layers. The welding is carried out with a current of 200–250 amp. in special moulds, and the tool is then subjected to mechanical and thermal treatment, the final sharpening procedure being the same as for ordinary high-speed tools.—S. K.

Safety Precautions during the Repair of Oil Storage Tanks by Electric Welding. D. E. Bondarev and A. V. Bibikov. (Avtogennoe Delo, 1948, No. 2, pp. 28–30). [In Russian]. Safety precautions, which have been satisfactorily adopted under the most exacting conditions during electric welding of oil storage tanks of 5000–10,000 cu. m. capacity are described. Such tanks are too large for satisfactory steam purging in winter, and among the measures recommended are the provision of an air-purged trench under the portion of the bottom to be repaired, or the erection of a hermetically sealed cabin, made of plywood with asbestos and tar paper, inside the tank with a pumped air supply. Sparking of 500-ml. samples of the atmosphere was adopted for the detection of dangerous concentrations of hydrocarbons.—S. K.

On the Results of a Conference on Welding in the Aircraft Industry. G. A. Maslov. (Avtogennoe Delo, 1948, No. 2, pp. 32–33). [In Russian]. A summary is given of the proceedings of a conference on welding held in December, 1947, at which the following were among the aspects discussed: Strength of welded joins and the control of their microstructure; heat distribution during welding; welding of heat-treated materials; argon-arc welding; technical properties of electrodes; welding of heat-resisting steels; butt-welding in serial processes; quality control of weld; welding machines; control of electrical parameters in welding; brazing of aircraft materials. Both electric and gas welding were considered, and mention is made of new methods.—S. K.

Welding a Drop-Shaped Tank. M. Ya. Chuskenkova. (Avtogennoe Delo, 1948, No. 3, pp. 22–25). [In Russian]. A description is given of the erection of a pear-shaped storage tank of 2000 cu. m. capacity on sandy soil. Electric welding was used, but few details of this are given.—S. K.

Preparation for Weld Joints of Great Thickness (Up to 35 mm.). V. I. Melnik and R. G. Shneiderov. (Avtogennoe Delo, 1948, No. 3, pp. 25–26). [In Russian]. The results of experiments undertaken to see if angles of bevelling for edge preparation of heavy sections could be reduced are given. Steel sheets, 33 × 400 × 100 mm., with bevelling angles of 20, 45, 55, and 60° and gaps of 2–6 mm. were manually butt-welded using an arc under standard conditions. The welds obtained were examined for penetration and subjected to mechanical tests, and recommended edge preparation for butt-welding steel sheets of thickness 20–35 mm., based on the results, is given together with estimated tolerances. The

forms of butt joints dealt with for various positions are the open double-**V**, the open double bevel; and the open single-**U**. S. K.

Repair of Sulphate-Cellulose Boilers of 125–140 cu. m. Capacity by Welding. E. D. Lonskii. (Avtogennoe Delo, 1948, No. 3, pp. 26–29). [In Russian]. The repair by arc welding of the leaking seams of a large vessel for boiling cellulose, designed to work at 175° C. and over 8 atm., is described. The operation was carried out in 30 stages by highly trained welders.—S. K.

The Repair of Diesel Engine Cylinders. L. A. Pankul. (Avtogennoe Delo, 1948, No. 3, p. 32). [In Russian]. A description is given of the repair of large cracks in American diesel engine cylinders by oxy-acetylene welding with a borax flux. The engines repaired in this way have given satisfactory service for a number of years.—S. K.

First Post-War Graduation of Welding Engineers from the Kiev Polytechnich Institute. M. N. Gapchenko. (Avtogennoe Delo, 1948, No. 3, p. 33). [In Russian]. A brief account is given of the reconstruction of the Kiev welding laboratories, and some of the more interesting researches carried out by the students are outlined. The main emphasis of the work has been on the mechanization of welding processes and the design of welding installations.—S. K.

Electrode Appliances for T-Welding with Spot-Welding Machines. G. P. Dobis. (Avtogennoe Delo, 1948, No. 3, pp. 29–31). [In Russian]. Clamping devices are described which enable **T**-welds to be made with a spot-welding machine. Details are given of three types of upper electrode clamp to deal with articles of the following sizes: Length up to 40 mm., cross section up to 7 sq. mm.; same length, cross section 7 to 175 sq. mm.; length 40–500 mm. and cross section up to 175 sq. mm. These can be used with lower electrodes either of the ordinary type which have been grooved, or with special clamping electrodes. Examples are given of joints made using the technique described and of the economies in time and material obtained.—S. K.

Determination of the Components of Electrode Coatings According to their Densities. N. N. Kriukovskii. (Avtogennoe Delo, 1948, No. 1, p. 30). [In Russian]. A table showing the densities of several electrode-coating components in an unspecified degree of subdivision or moisture is given; it provides a useful method of identifying such components after the determination of the density.—S. K.

Development of Electrode Production. (Avtogennoe Delo, 1948, No. 2, pp. 1–3). [In Russian]. Attention is drawn to the unsatisfactory position regarding the supply of electrodes in the U.S.S.R., and suggestions are made for improving the electrode industry.—S. K.

Electrodes Ts M-7. A. A. Alov. (Avtogennoe Delo, 1948, No. 3, pp. 1–5). [In Russian]. The properties of welding slags desirable for overhead work are considered, and an electrode coating to give a suitable slag is described. The coating was composed of the following: A rich hematite, low-carbon ferromanganese, potato starch, and water-glass. Tests showed that the best temperature for drying the coated electrode was 250–300° C., and it was found advisable to sieve-out the finest fractions before mixing. The mechanical properties of welds obtained with thicknesses of coating varying from 1 to 1·4 mm., diameters of electrode wire of 4 and 5 mm. and vertical, overhead, or horizontal weld positions were determined. Data are tabulated on the elastic limit, tensile strength, yield point, specific elongation and construction, and toughness.—S. K.

The Use of Electrodes Ts M-7 for Rapid Manual Welding. F. I. Pashukanis. (Avtogennoe Delo, 1948, No. 3, pp. 5–10). [In Russian]. The main characteristics of four types of coated electrode and the results of comparative tests for manual welding are given. Data are presented to show the effect on the losses during welding of the inclination of the electrode, and the effect on extent and rate of fusion of the linear speed of welding with particular reference to the coated electrode Ts M-7. The effects of adding iron powder to the coating material and the use of a thicker coating, comprising 65–75% of the weight of the core, are discussed and it is stated that the rate of welding can be greatly increased by using the thicker coating.—S. K.

On the Communication of Kuznetsov and Kunis in No. 6 of the Journal 'Avtogennoe Delo' for 1947. D. A. Dulchevskii. (Avtogennoe Delo, 1948, No. 3, p. 32). [In Russian]. The construction of the contacts described by Kunis and Kuznetsov for use in the welding of **H**-beams is said to be unnecessarily complicated, and a simpler design, which has been extensively tested, is shown.—S. K.

On the Article of A. V. Makushin, 'The Repair of the Drum of a Steam Boiler' published in No. 10 of the Journal 'Avtogennoe Delo' for 1947. L. A. Pankul. (Avtogennoe Delo, 1948, No. 3, p. 33). [In Russian]. A number of inaccuracies and misleading directions in Makushin's recent article are pointed out.—S. K.

Butt Weld Testing with the Hughes Supersonic Flaw Detector. (Machinery, 1950, vol. 76, May 11, pp. 667–668). The supersonic flaw detector (produced by Kelvin and Hughes Ltd.) can be applied to non-destructive detection of flaws in butt welds; it uses Perspex probes generating transverse waves.—R. F. F.

The Application to the Testing of Welds of a New Method for the Micro-Mechanical Testing of Metals. N. Mironoff. (Ossature Métallique, 1950, vol. 15, June, pp. 293–297). An account is given of the use of the Mironoff micro-mechanical tester (*see* Journ. I. and S.I., 1945, vol. 152, p. 120A) for determining the strength of welds. The importance is stressed of making localized tests and of studying the plastic properties of the metal near the weld. A description is given of tests carried out on a welded chromium–molybdenum steel at intervals of 5 mm.—J. C. R.

Standardization of Welders' Protective Glasses in Czechoslovakia. J. Kolář. (Svařování, 1950, vol. 10, May, pp. 67–69). [In Czech]. The author discusses the need for standardizing protective glasses for welders, and proposes a specification for square and circular glasses.—E. G.

The Danger of Back-fire in Oxy-acetylene Torches. Z. Duben. (Svařování, 1950, vol. 10, Feb., pp. 9–14). [In Czech]. On the basis of test results carried out at the State Metal Works, Chotěbor, the flash-back of the flame of oxy-acetylene torches is discussed. The ignition of the mixture inside the mixing chamber is influenced by the exit velocity of the gas mixture near the wall of the orifice and the temperature of the orifice tip. The flow from the mixer to the orifice must be continuous, so that it does not become detached from the wall. The higher the oxygen pressure and the lower the acetylene pressure the more difficult it is to prevent back-fires. Some torches are only immune from this trouble at a specific acetylene pressure.—E. G.

Underwater Welding and Cutting. G. S. Heathcote. (Tecnica e Industria, 1950, vol. 28, Feb., pp. 162–164). [In Spanish]. On the basis of his own practical experience, the author claims to have achieved satisfaction with the Peillon method of submarine welding. The Cox pistol, used for welding, cutting, and perforating in salvage work, is described. Precautions to be taken and conditions necessary for underwater joining and parting of metals are described.—R. S.

Flame-Cutting Underwater. O. Kracík. (Svařování, 1950, vol. 10, Mar., pp. 27–30). [In Czech]. Flame-cutting underwater with an oxy-hydrogen, oxy-acetylene, and oxy-hydrocarbon gas torch, and cutting with an electric arc are described on the basis of experience gained at the Polish port Gdynia and papers published in Poland.—E. G.

Oxygen and Other Gases and Their Application to Industry. R. E. Doré. (Journal and Transactions of the Society of Engineers, 1950, vol. 41, Apr.–June, pp. 29–51). A review is presented of the many industrial applications of oxygen and other gases. The cutting of steel includes hand and machine cutting, lancing, flame gouging, underwater cutting, hot cropping, and cutting stainless steel with the injection of a combustible powder or a powdered flux. Welding, flame hardening, flame spinning, and the enrichment of air for combustion are also dealt with. Argon, the hydrocarbons, and the rare gases are briefly touched on.—R. A. B.

CLEANING AND PICKLING

Development of Alkaline Cleaners. R. H. Tiers. (Metal Finishing, 1950, vol. 48, Apr., pp. 49–53). The introduction of bright nickel plating solutions made adequate cleaning methods essential and led to the use of alkali phosphate, silicate, or carbonate cleaners. Later developments have been concerned with formulating proprietary cleaners to remove specific types of dirt from given metals; they followed the direction of controlled blending of ingredients and the use of capillary active agents to improve wetting, dispersing, and

emulsifying powers. The desirable properties in an alkaline cleaner are in the following order of importance: (1) Dissolving power and alkalinity; (2) dispersing power for solids; (3) emulsifying power for liquids; (4) free rinsing; (5) low surface tension and wetting ability for soil and metal; (6) stability; (7) conductivity (for electrolytic cleaners); (8) low concentration for use; (9) economy; and (10) freedom from hazards—toxicity or flammability. A 'swirl' method for testing the efficacy of cleaners is described. This employs a plate, contaminated with a synthetic soil, compounded of cup grease, oil, powdered asbestos and charcoal, and ceresin. The plate is rotated horizontally at low speed in the cleaner at a controlled temperature and for a given time, and the percentage of soil removed is determined.—J. P.

Salt Baths Perform Variety of Cleaning Jobs on Most Metals. J. B. Campbell. (Materials and Methods, 1950, vol. 32, July, pp. 60–64). The sodium hydride and the 'Hooker' processes are described. In the former, the bath consists of caustic soda and 2% sodium hydride, and it is used at 700 to 800° F. The sodium hydride reduces oxides in the metal scale which is turned into a loose flakey mass. Water quenching removes this loosened scale, leaving a clean metal surface. The salt bath in the process developed by the Hooker Electrochemical Co. is also caustic, but it contains an unnamed oxidizing agent. Oxides in the scale are converted into higher oxides, resulting in swelling and cracking. Water quenching again removes the loosened scale. This salt, designated 'Virgo' salt, is operated at 850° to 1250° F. depending upon the particular application. The advantages and limitations of the salt method of descaling are listed, and examples of the applications of both these processes are described.—P. M. C.

PROTECTIVE COATINGS

Navy Develops a Wear-Testing Machine. G. W. Grupp. (Metal Finishing, 1950, vol. 48, July, pp. 66–67). The Engineering Experiment Station at Annapolis, Maryland, has developed a machine in which two sliders of piston ring material reciprocate over the surface of 24 chromium-plated steel panels under the same conditions of pressure, velocity, and stroke reversal as exist in diesel engine cylinders. During running of the test the panels are sprayed with artificially contaminated oil. After 50 hr. (equivalent to 1000 hr. with older machines) the panels are measured to 0·00001 in. for wear of the plating. With this accelerated testing machine, it is hoped (1) to determine the most satisfactory plating thickness under different plating conditions, (2) to learn the wearing qualities of different plating thicknesses with various bath conditions and compositions, (3) to understand better the effect of notches on the life of chromium-plated cylinder liners, (4) to ascertain what effect fatigue damage below the chromium plate has on the life of the deposit, and (5) to determine how the wearing qualities of diesel engine chromium-plated cylinder liners are affected by cracks in the plating, by the presence of residual stresses in the chromium or steel, or both, as a result of plating, and by possible brittleness due to hydrogen.—J. P.

Production Chrome Plating of Hand Tools. F. M. Burt. (Metal Finishing, 1950, vol. 48, Apr., pp. 59–62). The cleaning, copper strike, nickel and chromium plating sequence applied to a wide range of hand tools in a large American plant is described. An important point is the use of demineralized water for rinsing tanks and for make-up of all cleaning, acid-dipping, and plating solutions. This eliminates the contamination associated with tap water and dispenses with the need for sawdust or other drying-polishing medium. Production is of the order of 18,000–20,000 pieces/day with a crew of eight operatives. The bonus incentive plan for foremen is described in detail.—J. P.

Chromium Plating. J. Salauze, (Galvano, 1949, vol. 18, June, pp. 11–19). The equipment, solutions, and operating conditions for producing decorative chromium deposits on nickel are described. Particular attention is devoted to the use of the Hull cell for determining the effects of preparation of the nickel surface on the bright range of current densities and for controlling the CrO_3/H_2SO_4 ratio.—J. P.

The Thermodynamics of the Production of Metallic Coatings on Metals from Gaseous Metal Chlorides. T. P. Hoar and E. A. G. Croom. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept 15, 1950). The thermodynamic data of metal chlorides have been collected and applied to elucidate the mechanisms of the reactions involved in chromizing, siliconizing, and stannizing metals in atmospheres containing volatile metal chlorides. It is shown that chromizing iron in a hydrogen/chromous-chloride atmosphere can proceed partly by the interchange reaction $CrCl_2 + Fe \rightarrow Cr + FeCl_2$, and partly by the catalytic reduction $CrCl_2 + H_2 \rightarrow Cr + 2HCl$. Siliconizing of iron proceeds by interchange in a nitrogen/silicon-tetrachloride atmosphere and partly by reduction if hydrogen is present, whilst chromizing of nickel and molybdenum and stannizing of copper, possible only with hydrogen present, proceed entirely by catalytic reduction.

Influence of Various Additions to a Hard Chromium Bath on the Characteristics of the Chromium Layer. J. Dóskář. (Hutnické Listy, 1950, vol. 5, May, pp. 197–201; June, pp. 240–247). [In Czech]. The effect of organic and inorganic additions to chromium-plating baths on the hardness, wear resistance, and surface finish of the coating, and on the appearance of steel–chromium interface was investigated using an 8000-c.c. tank. Data on the test conditions and the results are given in tables and by graphs. The results show that to increase the cations it is advantageous to use cobalt, cerium, and sulphur uranyl salts. The addition of some heteropoly-acids widens the useful working range of electrolytes and confers the beneficial properties of the fluoride-base bath without its disadvantages.—E. G.

The Analysis of Chrome Plating Solutions. L. Silverman. (Metal Finishing, 1950, vol. 48, Feb., pp. 46–54). Procedures for the determination of the following components and impurities in chromium-plating solutions are given: (1) Chromic acid and tervalent chromium; (2) sulphuric acid; (3) iron; (4) copper; (5) zinc; (6) nickel; (7) aluminium and iron; (8) tin in tin–lead anodes; (9) antimony in antimonial lead anodes; and (10) chromium trioxide and sulphuric acid in anhydrous chromic acid.

An explanation of the catalytic action of the sulphate ion and the necessity for its presence in the chromium bath is offered.—R. A. R.

A New Coating Thickness Measuring Instrument. (Metal Finishing, 1950, vol. 48, May, pp. 64–66). An electromagnetic instrument is described. It consists essentially of a vertical glass tube with an engraved scale in which slides freely an iron core, carrying a plastic indicating sleeve at its upper end, and a copper-wire-wound solenoid which slides over the glass tube. In use, the tube is placed vertically in contact with the ferrous article, the coating thickness of which is to be measured, and the solenoid (energized by a 110-V. 60-cycle supply) moves down until the tip of the core makes contact with the surface of the article. The solenoid is then raised slowly until the core leaves contact with the surface; the scale reading marked by the top of the plastic indicator is noted. When the core is about to leave the surface, the pull exerted by the solenoid is just equal to the attraction between the core and the article. Since alternating current is used there occurs at this point a chattering of the core, which serves as a warning that the end-point is near; it also minimizes any chance frictional forces between the core and the glass tube. The relationship between coating thickness and scale reading is approximately parabolic and the readings are essentially unaffected by voltage fluctuations between 80 and 120 V. Since the solenoid and core become warm during use and thus change their magnetic properties, it is advisable to switch the instrument on about 10 min. before a reading is taken so as to allow equilibrium to be reached. The tip of the core and the articles to be tested must be kept clean. Rough electrodeposits should be burnished to provide a space to take a reading. Care should be taken to see that the articles are not magnetized before testing and that if the articles are thin they are backed up by a steel panel or block.

J. P.

Additive Compounds in Electroplating Baths. M. Rubinstein. (Metal Finishing, 1950, vol. 48, May, pp. 54–58; Aug., pp. 51–56, 58). The use and development of wetting agents, addition salts, and brighteners for electroplating baths are described briefly. The various theories advanced to account for the efficiency and specific mode of action of brighteners are reviewed at length. The general conclusion drawn is that all of them explain some, but that none explains all, of the features of brightening action. A comprehensive bibliography is included.—J. P.

Improvement of Power Factor in Electroplating Shops. R. Gautheret. (Galvano, 1950, vol. 19, Jan., pp. 15–18; Mar., 16–19). Examination of a large number of shops has shown that a low power factor is due principally to running of motors under part load and of transformers on open circuit. Care should be taken to see that this does not occur. To improve the power factor it is usual to employ capacitances in parallel with the motors.—J. P.

The Disposition of Articles in a Plating Bath. P. Michel. (Galvano, 1949, vol. 18, July, pp. 13–16; Aug., pp. 7–9; Sept., pp. 9–10). Since articles placed before a discontinuous row of anodes will receive a non-uniform current distribution, the movement of cathode bars is to be recommended. Although alternating movement is advantageous, semi and fully automatic plating lines offer numerous other benefits, such as controlled plating time, constant cathode area, and thus uniformity of deposit and constant output rates.—J. P.

Contribution to the Study of Pitting. (Galvano, 1949, vol. 18, Oct., pp. 9–11). It is assumed that pitting of nickel deposits is caused by the formation of hydrogen bubbles on the articles being plated. Hydrogen is discharged when the deposition potential of the metal is equal to that of hydrogen. In a properly controlled solution, the high concentration of metal around the cathodes ensures that this does not happen. If the bath is overworked, the diminution of metal concentration in the cathode film increases the metal deposition potential and thus allows hydrogen to be deposited, particularly if suspended solids are allowed to come in contact with the cathodes, for these reduce the hydrogen over-voltage. It is recommended that solutions be constantly filtered and maintained free from iron salts.—J. P.

POWDER METALLURGY

Powder Metallurgy—A Symposium on the Art and Practice of Powder Metallurgy. W. D. Labrum. (Journal of the American Society of Naval Engineers, Inc., 1950, vol. 62, Feb., pp. 63–96). A comprehensive account is given of the production of metal powders, the pressing, sintering, and after-treatment of the compacts, the equipment required, the properties of parts thus produced, and many industrial applications.—R. A. R.

Survey of Powder-Metallurgy Processes. Luis Auguet y Duran. (Revista de Ciencia Aplicada, 1950, vol. 4, Mar.–Apr., pp. 126–136). [In Spanish]. The present part of this series of articles deals with hot pressing. It describes the basic principles of hot pressing of metal powders, the presses and moulds used, and methods of measuring temperature. The author discusses the effects of this type of compression and the physical properties of the resulting compacts, especially density, hardness, resistance to tension, and other elastic properties. These characteristics are considered especially in relation to the period of compression. Finally, the combined effects of pressing and sintering are dealt with.—R. S.

The Production of Very Fine Metal Powders by Reduction with Hydrogen. M. Petrdlík. (Hutnické Listy, 1950, vol. 5, Mar., pp. 105–111). [In Czech]. The author has investigated the conditions for complete reduction of the oxides of tungsten, molybdenum, iron, nickel, cobalt, copper, and lead by hydrogen. A tubular furnace with two temperature zones, resistance heated, was used. The hydrogen flowed in the opposite direction to the powder. A method of calculating the water-vapour concentration in the furnace atmosphere is described.—E. G.

The Testing of Iron Powders and Sintered Iron. R. Schwalbe. (Stahl und Eisen, 1950, vol. 70, Mar. 16, pp. 219–227). Testing methods of iron powder metallurgy are divided into those for the raw material and those for the semi-finished or finished product. The chemical composition of an iron powder presents little difficulty, although the oxygen is not determined in the usual way. There are several ways of determining the physical characteristics of powders, but the results are not comparable and standardization of the processes is very desirable. Results of many tests are given and discussed, and it is established that with finished sintered iron bars there is a relation between the tensile and shear strengths and between the Rockwell C hardness and the bending angle in the bend test. Hardness test data cannot be converted into tensile strength.—R. A. R.

Metallurgical Aspects of Presintering and Sintering Cemented Carbides. G. E. Spriggs. (Journal of the Birmingham Metallurgical Society, 1950, vol. 30, Mar., pp. 5–25). The presintering and sintering of two types of cemented carbide, the tungsten carbide and cobalt, and the titanium carbide and cobalt alloys, are described, and the properties of the products at each stage are discussed.—R. A. R.

Metals and Refractories Combined in High-Temperature Structural Parts. J. B. Campbell. (Materials and Methods, 1950, vol. 31, May, pp. 59–63). This article is an up-to-date summary of the new high-temperature materials known as metal–ceramics, which are being developed to withstand the high service temperatures generated in rockets and jet engines. These materials, which are fabricated by powder-metallurgy methods, are combinations of refractory metallic compounds and pure metals. Typical combinations are: Aluminium oxide with iron or chromium; zirconium boride with nickel; boron carbide with iron; and titanium carbide with cobalt or nickel. Nitrides and silicides are also being considered. The properties at elevated temperatures, and the applications of several of the above materials are discussed in some detail. P. M. C.

Powder Metallurgy from the Design Engineer's Viewpoint. J. L. Bonanno. (Metal Powder Association, Proceedings of the Fifth Annual Meeting, Apr. 5–6, 1950, pp. 74–92). Several examples, which include wheels for toy locomotives, small side-bearing plates, a cluster gear, a bronze bushing, and a pressed iron car wheel, are described in order to show the substantial savings in cost when making them by powder metallurgy instead of by assembling parts made by conventional methods.—R. A. R.

Physical Investigations on Hard Metal Alloys. H. Krainer. (International Powder Metallurgy Conference, Graz, 1948: Archiv für das Eisenhüttenwesen, 1950, vol. 21, Mar.–Apr., pp. 119–127). The suitability of X-ray and magnetic methods of testing to control the production of sintered carbide products of tungsten carbide, cobalt, and titanium carbide has been investigated. The presence of the undesirable carbide W_2C can be detected with sufficient accuracy by X-rays. The presence of the undesirable double carbide $(WCo)_4C$ and other non-magnetic cobalt compounds can be determined by magnetic saturation measurements, but a field strength of 10,000 to 15,000 Oersted is required. Grain size, particularly that of the finer carbide particles, can also be determined by magnetic methods. The formation of TiC out of TiO_2 and carbon takes place over the intermediate stages Ti_2O_3 and TiO. TiO and TiC form solid solutions. R. A. R.

Oxidation of Cemented Carbides. R. Kieffer and K. Kölbl. (Powder Metallurgy Bulletin, 1950, vol. 5, May, pp. 38–39). The oxidation mechanisms of cemented carbides have been studied and illustrations are presented to show the types of oxide formed when three cemented carbides (compositions: WC 34·5%, TiC 60%, Co 5·5%; WC 94%, Co 6%; WC 82%, Co 18%) were heated in air at different temperatures.—R. A. R.

PROPERTIES AND TESTS

Study of the Shape of Tensile Curves for Metals and Their Physical Interpretation. C. Crussard and B. Jaoul. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Aug., pp. 589–600). Accurate tensile curves were obtained for pure aluminium using a micro-tensile (Chevenard) machine. The value of m in the parabolic formula $\sigma = \sigma_0 + A\epsilon^m$ (σ = Stress, ϵ = Elongation) is calculated by a differential method requiring no knowledge of σ_0. m varies along the curve dividing it into three zones of deformation: (*a*) Linear and very short—work hardening at the grain boundaries only, (*b*) parabolic ($m > 0{\cdot}5$)—intergranular and intracrystalline hardening, and (*c*) also parabolic (low value of m)—intracrystalline hardening due to the break-up of crystals. A critical examination of Dehlinger's hypothesis shows that this applies only when crystals have been broken up in this way. The behaviour of mild steels is analogous to that of aluminium with the levelling off corresponding to zone (*b*) and zone (*c*) marked owing to the rôle of carbon in blocking dislocations.—A. G.

Evaluating Notch Toughness. R. W. Vanderbeck and M. Gensamer. (Welding Journal, 1950, vol. 29, Jan., pp. 37s–48s). Test results from various types of notched specimen are reviewed. Tests were carried out over the range — 270° F.

to + 200° F. A transition occurs at relatively high energy levels which is probably due to a change of fibrous to a mainly granular type of fracture; this is called the fracture transition. Another transition occurs at low energy levels and lower temperature; this is due to a change in fracture of a small zone directly under the notch, and is called the ductility transition. With sufficient straining, ductility and fracture transitions occur at very nearly the same temperature. Tests on standard V-notched Charpy specimens and on similar specimens with a small fatigue crack at the bottom of the notch show that the absorbed energy increases gradually from low to fairly high values. No sharp transition to brittle behaviour but a sharp ductile transition at low energy levels is observed.—U. E.

Correlation of Test Results. C. F. Tipper. (Welding Journal, 1950, vol. 29, Feb., pp. 50s–57s). Various tests were carried out on a number of mild-steel ship plates to determine the transition temperature and to make a comparison with the normal tensile test. Results showed that some indication of the tendency to notch-brittleness can be obtained from ductility measurements, particularly the reduction of area. The energy absorbed in notch bend bests appears to depend mostly on the ductility of the steel. The appearance of fracture as a criterion of brittleness is only qualitative, but does influence all mechanical properties and gives the most consistent figures for determining the transition temperature. U. E.

Distribution of Relative Ductility in Steel Weldments. L. J. Klingler and L. J. Ebert. (Welding Journal, 1950, vol. 29, Feb., pp. 59s–73s). The dependence of the zone of low ductility in welds on the steel and on welding conditions and heat-treatment was investigated. Eccentric notch strength results are plotted against testing temperature and this shows that a zone of low ductility existed in two low-carbon steel ship plates of ¾-in. thickness at a distance 0·3–0·4 in. from the centre of the weld. The steel had been preheated at 100° F. Preheating and interpass temperature of 400° F. improved ductility in the critical zone and lowered the transition temperature from −20° to −45° F. Preheating to 1100° F. practically eliminated the zone of lowered ductility. Temperature measurements were carried out during welding showing that the critical ductility region had not been heated above the lower critical temperature and no change in microstructure occurred between the critical zone and the unaffected base plate. Slight hardening in the embrittled region was observed. This is thought to be due to phenomena such as supersaturation and precipitation of carbon or carbides from the α-phase at subcritical temperatures.—U. E.

Effect of Fatigue on Transition Temperature of Steel. J. M. Lessells and H. E. Jacques. (Welding Journal, 1950, vol. 29, Feb., pp. 74s–83s). Fatigue-impact tests were carried out on shipbuilding steel of 0·18% C and 0·21% C in the semi-killed, hot-rolled condition, having a tensile strength of 59·6 and 62·54 tons/sq. in. respectively. The specimens were round with a circumferential notch. It is shown that fatigue cracks develop and propagate at cyclic stresses below as well as above the endurance limit. When fatigue prestressing is carried out at stress levels resulting in crack formation, a large change in transition temperature and a considerable reduction in maximum impact energy occurs. If cyclically stressed so as to avoid fatigue cracks, the resulting transition curve shows little deviation from the original curve.—U. E.

Further Study of Navy Tear Test. N. A. Kahn and E. A. Imbembo. (Welding Journal, 1950, vol. 29, Feb., pp. 84s–96s). The paper presents further data on the application of the Navy tear-test method to the evaluation of notch-sensitivity characteristics of medium and high-tensile ship-plate steels. The energy which propagates bearing is measured or the percentage of shear in the fracture is used as a basis for evaluating the change from ductile to brittle fracture. Compositions and physical properties are given for 100 heats. Some special heats of medium-tensile steel ½ in. to 1¼ in. thick are included. About 50% of all medium-tensile steel samples tested in the as-rolled condition were below the quality required. Normalizing lowered the transition temperature.—U. E.

The Mechanism of Rupture in Metals. G. A. Homès and J. Gouzou. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Sept., pp. 678–692). Zinc and mild-steel test pieces which had been polished and etched were examined microscopically during testing. Three types of rupture were observed: (*a*) Pure cleavage, (*b*) cleavage and tearing, and (*c*) slip by translation followed by tearing. The first two were only found in zinc tested cold, the last in mild steel, and also in zinc tested hot. Different mechanisms may operate together during deformation, but twinning plays only a secondary rôle. No rupture is completely intercrystalline; intercrystalline fissures only develop in zinc, when the orientation of a crystal is opposed to all cleavage.—A. G.

A Proposed Microbending Mechanism of Plastic Deformation. M. K. Yen. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1949, vol. 185, pp. 1003–1004; Journal of Metals, 1949, vol. 1, Dec.). The theory of plastic deformation in crystals is discussed and a mechanism of microbending is proposed which postulates 'microbending sites.' These are illustrated schematically and are described as 'atomistically dislocated local curvatures,' which act as nuclei for the slip process.—G. F.

Residual Strains in Plastically Deformed Mild Steels. L. G. Finch. (Nature, 1950, vol. 166, Sept. 23, pp. 508–509). Values of lattice spacings in planes parallel to the surface of specimens were obtained by back reflection X-ray photographs and strains calculated from these. An interpretation of the results is suggested and the behaviours of ferrite matrices in steels with spheroidal carbide and ferrite–pearlite structures are compared. The systematic residual strain in the ferrite matrix is confined to the plastic region and determined mainly by the geometry of the specimen and its anisotropic characteristics.—A. G.

Residual Strains in Plastically Deformed Mild Steels. G. B. Greenough. (Nature, 1950, vol. 166, Sept. 23, pp. 509–510). Earlier values of residual strain are corrected to allow for the effect of impurities in the iron. Two further series of measurements were made. When these three sets of values are plotted against the orientation function ϕ, the gradients of the straight lines obtained are proportional to the applied stress (in accord with Heyn's theory). The average residual stress is not zero, so in addition to Heyn intergranular stresses there must be a compressive stress, probably in the surface layer. A. G.

Crystal Interaction and the Brittleness of Metals. P. Laurent and M. Eudier. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Aug., pp. 582–588). The classic theory of elasticity is modified to include the effect of granular structure on strain distribution by considering each crystal in a pseudo-isotropic medium. Values for crystal interaction, modulus of elasticity and Poisson's ratio are in good agreement with experimental results. The effect of crystal interaction on the maximum shear strain and maximum principal strain as well as the conditions of triaxial stress determining whether plastic deformation or brittle rupture occurs are calculated. A. G.

Shearing of Metal Bars. T. M. Chang and H. W. Swift. (Journal of the Institute of Metals, 1950, vol. 78, Oct., pp. 119–146). Stresses, metal flow, and crack propagation in the shearing of ½-in. thick bars of most industrial metals have been studied. There are two chief modes of fracture in shearing without clearance. Ductile materials undergo a bodily sliding action along the line of shear with the displaced particles maintaining their adhesion until final separation at full punch penetration. Other materials develop cracks, and the metal separates either when one of the cracks propagates itself through the whole thickness of the bar or when the cracks from the punch and die meet; tongues of metal develop in the former case, whilst a clean fracture results from the latter. The optimum clearance for a clean fracture and least strain work ranges from 5 to 10% for the harder metals such as copper, brass, and mild steel.

Dullness of cutting edge and tensile overstrain tend to increase the maximum shearing load; dullness increases the punch penetration at failure whilst overstrain tends to reduce it. There seems to be no definite and useful relationship between shearing and tensile test results.—R. A. R.

Some Thoughts on the Effect of Structural Imperfections on the Physical Properties of Metals. N. F. Mott. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Aug., pp. 291–296). Three types of deformation must be distinguished, *viz.*: (1) Where the grain structure is deformed; and (2) where there has been movement of the grain boundary (*a*) perpendicular to, or (*b*) parallel to the direction of the boundary. A

mathematical treatment of these three types of deformation is developed and is supported by experiment.—B. G. B.

Drilled Rotors of Turbogenerators. S. Todl. (Elektrotechnický Obzor, 1950, vol. 39, May, pp. 165–170). [In Czech]. An analysis of stress concentrations is carried out which shows that the standard methods for strength calculations are not satisfactory. The analysis described shows that the peak stresses in a rotor of a turbogenerator can be reduced by making them of structural steel, because in such steels stresses are transferred to adjacent layers of the material by the slight deformations which occur where there are peak stresses. The author advocates the use of drilled rotors as these present several advantages, namely, sufficient material for mechanical and other tests, and greater possibility of relieving internal stresses. The author also investigates the causes of failures of turbogenerator rotors and advocates revision of the present methods of strength calculation so as to take into account the plastic deformation of steel.—E. G.

Calculation of Vessels the Material of Which is Strained above the Limit of Proportionality. J. Němec. (Strojnický Obzor, 1950, vol. 30, June, pp. 82–85). [In Czech]. The basic principles of strength calculations for vessels the material of which is strained above the limit of proportionality are dealt with. The author investigates the case of uni-axial tensile stress in conjunction with the girder theory and indicates the possibility of applying the results to calculate local tensile stresses in shell plates, and tri-axial tensile stresses in thick-walled vessels.—E. G.

The Use of Wire-Resistance Strain Gauges in Automobile Engineering, with Particular Reference to the Measurements of Strain in Vehicle Structures. J. R. Bristow, P. Metcalf, and C. H. G. Mills. (Institution of Mechanical Engineers, Automobile Division, 1950, Advance Copy). Dynamic strain determination is discussed with reference to measurements made on the frame and superstructure of a double-deck public service vehicle under road conditions, and typical strain records are given. The portable four-channel dynamic-strain recording equipment developed at the Motor Industry Research Association for the above type of work is described.

R. A. R.

Residual Stresses Set up in High Chromium Stainless Steel by Grinding. L. A. Glikman, T. P. Sanfirova, and V. A. Stepanov. (Journal of Technical Physics, U.S.S.R., 1949, vol. 19, No. 4, pp. 441–447). The residual stresses set up by grinding were determined using seven strips (8·7 × 0·8 × 0·135 in.) of 13–15% chromium steel and two strips of 0·13–0·23% carbon steel. These were ground on one side, and the deflections, after removing successive thin layers of metal from the other side by etching, were measured electrically. The stresses were calculated by Davidenkov's formula. Temperatures above the transformation point can be attained momentarily by grinding austenitic steels. There is an increase in volume due to the formation of martensite. This reduces the tensile stress at the surface and sets up strong compressive stresses in a thin layer immediately below the surface.—R. A. R.

A Note on High-Speed Fatigue Testing. R. P. McMurrich. (Australian Institute of Metals: Australasian Engineer, 1950, July 7, pp. 49–50). In order to reduce testing time, several rotating cantilever machines have been designed to run at 12,000 r.p.m. The specimens are 0·25 in. dia. at the working section, and reversed bending stresses up to 60 tons/sq. in. can be applied. The machines are driven by 0·5-h.p. motors. Test results indicate that the high speed of testing has little effect on the fatigue value.—P. M. C.

The Relation between Indentation Hardness and Strain for Metals. J. H. Palm. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1949, vol. 185, p. 904; Journal of Metals, 1949, vol. 1, Nov.). From the basis of the formula relating true stress and true strain for monotonic deformation of plastic metals in single tension and compression, the validity of a similar formula relating hardness and strain is examined. It is deduced that the ratio of the asymptotic or final values of hardness and stress is constant at a value of 2·8 for all plastic metals. This value is found to agree satisfactorily with experimental results.

G. F.

The Meyer Law for Hardness Tests. E. Jimeno and J. Terraza. (Nature, 1950, vol. 166, Aug. 26, p. 359). The relation between load and diameter $P = ad$ (due to Meyer) governing the indentation test is checked and new meaning given to the constants 'a' and 'n', starting from the classical laws of elasticity. Beginning with Hertz's formula for the diameter of the indentation, the equation

$$P = \frac{E.d_o^{\eta}}{3(1-\nu^2)\,D} \cdot d^{3-\eta}$$

is derived, where d_o is the impression diameter at the elastic indentation point, η is a constant, E is Young's modulus, and ν is the reciprocal of Poisson's ratio. From this the Meyer constants are

$$a = \frac{E.d_o^{\eta}}{3(1-\nu^2)\,D} \text{ and } n = 3-\eta$$

These values are consistent with experimental results. Equations are also given for an elastic hardness relation and for the Hertzian hardness.—A. G.

Hardness Measurement.—Critical Anaylsis of the Shore Method of Hardness Measurement. L. Jeníček and J. Dobrý. (Hutnické Listy, 1950, vol. 5, Apr., pp. 167–172). [In Czech]. The authors have carried out hardness measurements by the Shore, Vickers, and Rockwell methods on specimens of various shapes and sizes made of various steels. For a steel cube weighing 1·5 kg. the Shore hardness at the edges was up to 15% lower than at the centre of the faces whilst there was scarcely any fluctuation in the hardness values obtained by the Vickers or Rockwell instruments. Measurements on larger specimens showed that the Shore hardness increased with increasing size. The results show the influence of (*a*) the position of the impression, (*b*) shape with specimens of equal weight and (*c*) the weight of the specimen. The authors explain the difference between the curves published in different countries for converting hardness values from one scale to another by differences in the damping capacities of the specimens. Suitable portable hardness measuring instruments of Czech manufacture are now available.—E. G.

Microhardness of Carbon Steel. W. Loskiewicz, W. Haczewski, and Z. Wojcik. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 1, pp. 37–47). [In Polish]. Micro and macro methods have been applied to the examination of the hardness of heat-treated steels. The measurements have shown that the microhardness is generally lower than that shown by macro methods. The tests demonstrated that a decrease in microhardness is evident in the bainite–pearlite transition range.—W. J. W.

Friction. F. P. Bowden. (Nature, 1950, vol. 166, Aug. 26, pp. 330–334). A simple account is given of the laws of friction, area of contact, local welding, etc. Between sliding surfaces the temperature may rise locally to 500° or 1000° C. The coefficient of friction of plastics with branching side chains capable of interlocking (*e.g.*, Perspex) is high, while for simple long-chain compounds it is low. 'Teflon,' in which the hydrogen atoms are replaced by fluorine, has the very low value of $\mu = 0{\cdot}04$. This is due to the screening effect of the negatively charged fluorine atoms. Sintered copper with the surface impregnated with 'Teflon' should prove a useful anti-friction material having $\mu = 0{\cdot}05$.—A. G.

Metal Transfer from Piston Rings to Cylinders during 'Run-In.' C. D. Strang and J. T. Burwell. (Institution of Mechanical Engineers, Automobile Division, 1950, Advance Copy). Piston rings with radio-active wearing surfaces were used to study the microwelding between rings and cylinder wall when running-in a small water-cooled internal combustion engine. Microwelding and the accompanying transfer of metal were present under the mildest conditions of engine operation, including movement of the engine with cylinder-head removed.—R. A. R.

The Control of Surface States by Fluorescence in Metallurgy. M. Déribéré. (Revue de Métallurgie, Mémoires, 1950, vol. 47, Sept., pp. 704–705). The method is useful for detecting fine cracks, fissures, and faults. Details of application (by smearing or soaking) and choice of fluorescent material are briefly given.—A. G.

Flux Densities for Magnetic Particle Inspection. T. E. Hamill. (Welding Journal, 1950, vol. 29, Feb., pp. 105–114). Flux densities were measured over a current range of 200 to 2000 amp., at the surface and up to 5 in. below the surface of the steel. Maximum flux density occurred at the highest amperage, *i.e.*, 650 gauss were obtained for a $\frac{1}{2}$-in. radius round specimen and only 320 gauss for 6-in. thick plate.

Increase in diameter of the round from ¾ in. to 7½ in. decreased the amount of flux and an increase of plate thickness of ½ in. to 6 in. resulted in increase of flux when electrode connections were made at the centre of each end of the rounds and one end of the plates. The rate of decrease of flux density with increase in depth in various shapes and sizes of steels is not uniform and varies with respect to the amount of current, size and shape of piece, and electrode location and spacing. Maximum flux density of weld specimens made with 3-in. plate was higher than with those made from 1½-in. plate for all currents in both the as-welded and stress-relieved conditions. Stress-relieving welded specimens at 1175° F. increased the flux density from 75 to 100% over that obtained in the as-welded condition. Specimens having a large amount of weld metal *i.e.*, T-fillets and corner joints showed greater increases than the T-double-bevel and butt joints. Stress-relieving 1½-in. plate with welded corner joints increased the flux density 18% over that obtained in the as-rolled plate. Results with artificial defects in the ¾-in. wall of a tube showed that there exists a definite relationship between the flux density obtained with the gaussmeter and depth of hole.
U. E.

Steel, the Physicist and the Electrical Engineer. N. F. Astbury. (Australian Institute of Metals: Australasian Engineer, 1950, June 7, pp. 59–65). The author's topic is applied magnetism. The most recent theory of magnetism, that of magnetic 'domains' within grain boundaries, is described and the marked anisotropy of the crystal lattice from a magnetic viewpoint is discussed. This phenomenon is exploited in silicon irons, which are used in electric generating and transmission equipment. In order to miminize power loss on magnetization it is often desirable to induce this preferred orientation in the sheet. This is accomplished by cold rolling followed by suitable heat-treatment. The author discusses in some detail the properties of orientated materials and ends with a short explanation of permanent magnetism.
P. M. C.

Preferred Domain Orientation in Permanent Magnet Alloys. M. McCaig. (Nature, 1950, vol. 165, June 17, p. 969). A theory is advanced to explain the increase by up to 100 oersteds in the coercive force of Alcomax II when cooled in a magnetic field. If the direction of magnetization is parallel to a compressive stress or perpendicular to a tensile one, the energy of interaction $\lambda\ \sigma$ (λ = magnestostriction, σ = stress) may have a trigger action in relieving precipitation stresses along certain preferred slip planes. The stresses tending to produce domain orientation would then be retained while others were removed. Alternatively, the preferred slip planes might influence further precipitation.—A. G.

Internal Microstrain and the Deformation and Failure of Metals. I—The Possibilities of Using the Correlation between Internal Microstrain and Magnetic Properties in the Study of Metal Failure. P. Cavanagh, T. Wlodek, B. Chalmers, and U. Martius. (Transactions of the Canadian Institute of Mining and Metallurgy, 1950, vol. 53, pp. 166–168: Bulletin, 1950, vol. 43, May, pp. 251–253). Internal microstrains in metals are defined, and it is deduced that they govern both magnetic and mechanical behaviour. A magnetic test method for determining microstrains is outlined. Tests are in progress to investigate whether such a method will give sufficiently accurate values for predicting the performance of metals under service conditions.—J. E. D.

Recent Developments in Non-Destructive Testing by Electrical and Magnetic Methods. W. Jellinghaus. (Stahl und Eisen, 1950, vol. 70, June 22, pp. 552–560). Developments, particularly during the last ten years, of non-destructive electrical and magnetic testing methods are reviewed. In these methods, electrical or magnetic quantities are measured which are related to the desired properties in a manner which must be determined for each type of material or article. There are but few basically different methods available, but by applying them in suitable ways a multiplicity of uses is possible. The methods, described with reference to specific instances, may be used for testing for uniformity of mechanical properties, wall thickness, adhesion, layer thickness, surface decarburization, depth of case-hardening, local inhomogeneities, and faults such as cracks, laminations, and inclusions. Mention is also made of oil exudation and fluorescence methods for crack detection.—J. P.

Progress in Non-Destructive Testing with Ultrasonics. O. Rüdiger. (Stahl und Eisen, 1950, vol. 70, June 22, pp. 561–565). Various applications of ultrasonics for testing for cracks, laminations, cavities, and welding faults as well as for wall thickness are described. They may be divided into four groups. With intensity methods, the specimen, immersed in a fluid, is subjected to a wide ultrasonic beam and the intensity of the emergent beam is explored with a suitable microphone. Ultrasonic waves are almost completely reflected at a solid–gas interface so that at a place corresponding to a fault the intensity falls to zero. In the pictorial method the emergent beam is passed through a 'lens' and focused on a layer of liquid containing suspended aluminium flakes. These flakes orient themselves parallel to the wave front of the sound and thus the reflectivity of the aluminium suspension is a function of the intensity. Illumination of the trough containing the flakes from below allows a 'picture' of the whole test piece to be seen from above, the brighter areas indicating the site of a fault. These two methods indicate the whereabouts but not the depth of a fault. The third method has not this disadvantage. A regular series of ultrasonic pulses is projected from a quartz emitter into the material. These are reflected from the lower surface and may be received at the upper surface by another quartz crystal or, by suitable switching, by the emitter. The time required for the double journey may be measured or preferably indicated on a cathode-ray oscilloscope. If there exists a fault within the material, reflection also takes place from this. On exploring the surface with the emitter head, the oscilloscope screen shows two 'peaks,' one corresponding to the emitted pulse and the other to the reflected pulse. When the head is over the site of a fault, another 'peak' occurs between these two and its position indicates the depth of the fault. In the resonance method the frequency of the sound emitted by the quartz exploring head is varied until the metal sheet is set in resonance. When this occurs, the power taken by the high-frequency generator increases sharply and thus gives an indication of the occurrence of resonance. The resonance frequency can be related to wall thickness by preliminary calibrations.—J. P.

Thermal Expansion Characteristics of Stainless Steels between −300° and 1000° F. D. E. Furman. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1950, vol. 188, pp. 688–691; Journal of Metals, 1950, Apr.). A study of the expansion characteristics of several annealed chromium–nickel stainless steels is described, the mean and instantaneous coefficients of linear expansion being determined over the temperature range − 300° F. to 1000° F. It is found that the highest coefficients of expansion can be expected in the steels with the highest iron contents, and any decrease in the iron content tends to lower these values. The influence of austenite instability on the expansion characteristics is shown to be of small importance.—G. F.

Graphitisation of Steels. L. C. Bogan. (Australian Institute of Metals: Australasian Engineer, 1950, Jan 7, pp. 65–72). The article is a review of current ideas relating to graphite in steel. The formation of graphite in two hypereutectoid steels is discussed and illustrated by microphotographs. One steel contains 1·2% C, 0·6% Si, and 0·3% Mn, and the other 1·4% C, 0·26% Mn, 0·085% Si, 0·020% Al, and 0·018% Al_2O_3. The growth of graphite nodules along ferrite grain boundaries is shown. Factors which favour and inhibit graphitization are next discussed. Steels 'fine-grained' with aluminium are more sensitive to carbide dissociation than semi-killed, or 'coarse-grained' silicon-killed steels. Increasing silicon content favours graphitization in both ferrite and austenite. Chromium and molybdenum both tend to stabilize carbides below the critical range. Plastic strain increases the rate of graphitization and in some cases will result in preferred orientation of the graphite nodules. The best heat-treatment to inhibit graphitization for low-alloy steels appears to be a pretempering treatment just below the lower critical range, about 1300° F. The phenomena of nucleation, diffusion, and growth are described. There are 22 references.—P. M. C.

On the Question of the Strength of Metals in the Welding Process. N. N. Prokhorov and P. M. Liubalin. (Avtogennoe, Delo, 1948, No. 11, pp. 16–18). [In Russian]. An account is given of experiments in which the plastic properties of six steels were investigated by impact tests at various temperatures during cooling from temperatures in the 800–1350° C.

range, by quantitative evaluation of cracks on butt-welded test pieces after heating to 1350° C. and cooling, and by dilatometric methods. It is concluded that the plasticity of pearlitic steels, under temperature conditions similar to those in welding, diminishes in two temperature ranges, 1000° to 1400° and 25° to 200° C.; the plasticity of pearlitic steels throughout the cooling range is least when the heating temperature has been greatest; high-temperature plasticity corresponds to the observed tendency to cracking; high-temperature brittleness is due to intercrystalline rupture; plasticity under welding conditions is the main criterion of the tendency of steels to crack.—S. K.

Creep Testing Equipment. R. R. Brooks. (Australian Institute of Metals: Australasian Engineer, 1950, July 7, pp. 47–49). Two miniature creep-testing machines are described, both being used for the routine testing of turbine rotor-blade steel. The specimen gauge length is 0·625 in. and the diameter 0·1785 in. Creep strain is not measured, the specimens simply being required to withstand a certain load and temperature for a minimum time. One machine was developed by Rolls-Royce Ltd., and it applies the load (maximum 0·75 tons) by dead weight. The other, developed by Wm. Jessop and Sons, Ltd., is manufactured by S. Denison aud Sons, Ltd., and applies the load through a 10:1 lever. The furnaces are wound with 22 S.W.G. Brightray or Ni-chrome wire.—P. M. C.

Equipment for the Measurement of Cold Creep in Steels. F. Levi. (Costruzioni Metalliche, 1949, vol. 1, Sept.–Oct., pp. 2–4). After briefly explaining the high costs involved in equipping a laboratory for the measurement of hot creep such as that at the Amsler works in Switzerland or at the Baldwin Locomotive Works in the U.S.A., the author describes the measurement of cold creep. The apparatus considered consists briefly of a rigid frame 9 ft. long in which is fitted a wire. The wire is put in tension and the differential movement between wire and frame is measured.—M. D. J. B.

Creep Tests on High Tensile Steels. J. Raineri. (Costruzioni Metalliche, 1949, vol. 1, Sept.–Oct., pp. 4–6). The problem of creep in steels is discussed with special reference to the drop in tension in the high-tensile wires of prestressed concrete. A theory for creep is developed and results are given of tests carried out at the Swiss Federal Laboratory for the Testing of Materials, and by the author.—M. D. J. B.

Babcock & Wilcox Company Installs New Laboratory for Creep and Stress Rupture Studies. (Industrial Heating, 1950, vol. 17, June, pp. 988–994). This article discusses briefly the importance of complete data on creep and stress rupture properties of carbon steels, alloy steels, and other metals and goes on to describe equipment in the new Babcock and Wilcox laboratory at Alliance, Ohio, for the measurement of these properties.—J. A. L.

The Relaxation of Metals at High Temperatures. A. A. Chitkov. (Hutnické Listy, 1950, vol. 5, Feb., pp. 52–56). [In Czech]. Two theories are available to explain the relation between the relaxation and the creep phenomena; these are the time-hardening and the strain-hardening theories. However, test results indicate that neither of them correctly defines the relation because the mechanism of the plastic deformation and the internal micromechanical process are different for the two phenomena. The author recommends research work on relaxation independently of work on creep. Results of Russian research on this subject are given.—E. G.

Belgian Achievements in Heat-Resisting Steels. O. L. Bihet. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Aug., pp. 221–230). After giving a brief description of the work since 1920 the author gives details of research now being undertaken to develop steels for use in steam boilers. For boiler tubes, where the oxidizing conditions are not severe, a steel having the following analysis has been found suitable. C $<$ 0·15%, Cr 2·25%, Mo 1%. A steel for use at high temperatures, where resistance to creep and oxidation is necessary, has been produced containing Cr 9% and Mo 1%. Full details of the creep tests carried out on these two steels are given. The difficulties in obtaining a steel suitable for the manufacture of bolts are discussed. A review is also given of the work now being carried out at the Centre National de Recherches on the theoretical study of the causes of heat failure of steel.—B. G. B.

Deformation Characteristics of Five Grey Cast Irons at 400 and 500 deg. C. C. R. Tottle. (Institute of British Foundrymen: Foundry Trade Journal, 1950, vol. 89, Sept. 21, pp. 273–281). Five grey cast irons, manufactured by the Meehanite process were critically examined at 400° C., and incompletely so at 500° C. The compositions of the irons tested were (1) basic iron, 2·91% total carbon, 1·34% silicon, 0·31% copper; (2) basic iron plus 0·51% molybdenum; (3) basic iron plus 1·51% copper and 0·41% molybdenum; (4) basic iron plus 1·36% copper and 0·82% chromium; (5) 4·08% silicon plus 1·26% chromium and 0·9% molybdenum The deformation at the above temperatures was measured in short-time tensile tests, in high-sensitivity creep tests of 2500 hr. duration and in stress-to-rupture tests. Unstressed bars, inserted in the creep furnaces, showed no growth after 10,000 hr. exposure, and no breakdown in microstructure was observed in stressed bars even at 500° C. The author's conclusions are: (1) The ductility was increased at 400° and 500° C. as measured by the short-time tensile tests. The modulus of elasticity was decreased at both temperatures, rupture strength was only slightly affected at 400° C., but considerably at 500° C. (2) The effect of increasing stress in the creep at 400° C. gives a normal increase in total strain at any duration, and a slow rise in creep rate at the constant or decreasing stage of the creep curve. (3) The normal creep tests at 400° C., show extremely small values of deformation compared with most materials used at high temperature, and the total strain, after a life of several years, even for stresses of the order of 10 tons/sq. in. must be very low. (4) The duration, before rupture at high stresses, increases considerably with decrease in stress below the short-time rupture strength and ductility appears to rise as the duration is prolonged by lower imposed stresses. This increase in ductility appears to take place in the tertiary stage of creep. (5) Extrapolation indicates that stresses of the order of 5000–8000 lb./sq. in. in tensile, could be applied at 400° C., to limit the deformation to less than 0·1% after 100,000 hr. Extrapolation to total deformation of 1%, at 10,000 hr. would indicate that stresses approaching 20,000 lb./sq. in. may be possible. (6) No measurable growth occurred after 10,000 hr. at 400 and 500° C. in unstressed bars, and microscopical examination indicated that no structural breakdown occurred at either temperature, at the conclusion of creep tests of 2500 hr. duration. (7) Molybdenum plays an important part in improving creep resistance, and chromium–copper iron is only slightly inferior. A silicon–chromium–molybdenum iron is inferior in creep, though it perhaps has a superior oxidation resistance.—J. E. W.

Surface Effect Occurring on High Carbon Steels Heated and Cooled *in vacua*. G. C. Smith and M. J. Olney. (Research, 1950, vol. 3, Apr., p. 194). The formation of a grey-black surface film on hypereutectoid 1·15% carbon steels, heated into the austenite region and cooled in high *vacua*, has been observed. Investigation by electron diffraction, X-ray powder photography, and friction measurements, proved the film to be graphite. It appears that this graphite formation is characteristic of high-carbon unalloyed steels, and has been shown not to be due to external or vapour phase contamination. No interior graphite formation can be found.

C. J. B. F.

Contribution to the Theory of the Elimination of Hydrogen from Metals by Melting under Vacuum. L. Fekete. (Bányászati és Kohásati Lapok, 1950, vol. 5, June, pp. 375–381). [In Hungarian]. The author carries out a mathematical investigation of the relation between the hydrogen bubbles formed in the vacuum process of removing hydrogen during the melting of the metal and the amount of hydrogen remaining in the melt after the vacuum treatment, both as functions of the initial hydrogen content, the depth of the metal bath, and the pressure.—E. G.

Influence of Boron on the Hardenability of Steel. E. Theis. (Stahl und Eisen, 1950, vol. 70, Apr. 27, pp. 382–384) Experimental work on the hardenability and structure of boron steels is reviewed. It is concluded that boron enters the iron lattice interstitially, provided that nitrogen and oxygen are absent. When present to the extent of 0·001–0·002% it increases the hardenability as judged by the Jominy end-quench test. Higher proportions than the above have no further influence. Boron undissolved in austenite or boron nitride or oxide are without effect.—J. P.

Some Notes on Alloy Steels Containing Lead. (Samuel Fox

& Co., Ltd., 1950). A short account with numerous illustrations is given of the production, manipulation, heat-treatment, mechanical properties, machinability, and economics of lead-bearing steels. The bibliography contains 11 references.—R. A. R.

Alloy Steels for Plastic Moulds and Hobs. L. Sanderson. (Metallurgia, 1950, vol. 41, Mar., pp. 248–250). Recommendations are made on the composition, heat-treatment, and use of alloy steels for moulds for plastics, and for the hobs for making moulds. The compositions of the steels are:

Steel No.	C, %	W, %	Cr, %	Mn, %	Mo, %	Ni, %
1	0·3	0·5	1·0	...	...	1·3
2	0·25	...	0·8	...	0·5	2·5
3	0·35	...	14	...	...	...
4	1·5	...	12	...	0·75	...
5	0·1	...	...	0·4	...	...
6	0·1	...	14·0	...	...	...
7	0·1	...	0·6	0·2	...	1·25
8	0·15	...	1·5	0·45	...	3·5
9	0·15	...	...	...	0·3	1·5
10	0·3	0·5	1·0	...	...	1·3
11	1·5	...	12	...	0·75	...
12	0·5	...	0·8	0·4	0·5	1·5
13	0·9	0·5	0·5	1·2	...	...
14	1·2–1·3	4–5	0·7–0·8	0·2–0·3	...	...

Steels 1 to 4 are for machined moulds, steels 5 to 10 for hobbed moulds, and steels 11 to 14 for master hobs. The surface hardnesses obtainable after various forms of heat-treatment are also given.—R. A. R.

Steels for Agricultural Machinery. B. Hedde d'Entremont. (Métallurgie, 1950, vol. 82, Mar., pp. 185–189). Steels for agricultural machinery are compared with steels for automobiles, and analyses of steels for various implements and parts are listed. Four main classes of equipment are considered: Motor elements; cultivating implements such as ploughs; harvesting equipment; and hand tools.—R. S.

Steels for Specialized Applications. J. M. Mowat. (West of Scotland Iron and Steel Institute, Mar., 1950, Preprint). Reference is made to a few special steels with distinctive properties which have been developed to meet some modern engineering requirements. It is shown that forging, heat-treatment, and origin of the steel influence its efficiency in service. Particular attention is given to steels for turbine rotors, and to the manufacture of forged-steel work rolls.

R. A. R.

How to Choose a Stainless Steel. L. Guitton. (Métaux et Corrosion, 1950, vol. 25, Apr., pp. 91–99; June, pp. 164–169). The author gives some general indications of the factors affecting the selection of a stainless steel. The broad classes of stainless steel are described and data are given on the behaviour of stainless steels in various chemical media. Examples of the use of stainless steel in the dye, transport, aeronautical, medical, food, and petroleum industries, and in the domestic and decorative spheres are described with many illustrations.—R. A. R.

Stainless Steels—Their Selection and Applications. T. C. DuMond. (Materials and Methods, 1950, vol. 31, May, pp. 83–98). This is a very detailed and informative article intended to guide the production engineer. The general characteristics of stainless steels are described under the headings corrosion resistance, carbide precipitation, resistance to scaling, mechanical properties, high-temperature properties, and fabricating characteristics. The austenitic, ferritic, and martensitic types are then discussed, and the more important features of the 28 recognized American grades of stainless steel are pointed out. Hints on the selection of suitable grades for various service requirements, and the suitability for different forming operations, are given. The compositions, properties, machining speeds and corrosion resistance in 92 media are given in tables.—P. M. C.

Chemical Engineering Materials of Construction—Stainless Steels and Other Ferrous Alloys. W. B. DeLong and P. H. Permar. (Industrial and Engineering Chemistry, 1950, vol. 42, Oct., pp. 2009–2019). Information published during the last half of 1949 and early 1950 is summarized. Subjects are reviewed under the following headings: (1) Evaluation methods, including the value of various methods of testing corrosion resistance. (2) Corrosion. (3) Mechanical properties and structure. (4) High-temperature properties. (5) Welding, oxygen cutting, silver brazing, and soft soldering stainless steels. (6) General, which includes manufacture, machining, surface treatment, and applications. (7) High-silicon irons. (8) Austenitic manganese steels and iron–nickel alloys. There are 238 references.—C. J. B. F.

Chemical Engineering Materials of Construction—Iron, Mild Steels, and Low Alloy Steels. C. P. Larrabee and S. C. Snyder. (Industrial and Engineering Chemistry, 1950, vol. 42, Oct., pp. 1986–1990). Information published in the last few years (1947–49) is summarized. Subjects reviewed are: (1) Irons, including nodular cast iron, ductile cast iron, the determination of traces of magnesium and cerium, corrosion of cast-iron water mains by sulphate-reducing bacteria. (2) Carbon steels, including galvanic corrosion, the effects of hydrofluoric acid and hydrogen, brittleness and low temperature properties, and corrosion and its inhibition. (3) Alloy steels, including their use for pipes, fittings, and valves. (4) High-strength, low-alloy steels and their advantages. There are 37 references.—C. J. B. F.

New Stainless Steel Used for Cold Headed and Upset Parts. (Materials and Methods, 1950, vol. 31, Feb., p. 59). This is a short review of a new austenitic steel, called Carpenter Stainless No. 10, analysis: 0·08% max. carbon, 16·0% Cr, 18·0% Ni. Because it does not work-harden rapidly, this steel is expected to find wide use in the making of such parts as cold-headed bolts, recessed head screws, and other parts that require severe cold-working operations. The physical constants and mechanical properties are listed, a tensile strength of 75,000 lb./sq. in. and Brinell hardness of 145 being obtained on water-quenching from 2000° F.—P. M. C.

Stainless Steel—Its Development and Use. V. W. Whitmer. (Iron and Steel Engineer, 1950, vol. 27, Feb., pp. 70–73). A short history of the development of stainless steel and its adoption by various industries is given. The heat-resisting, magnetic, and corrosion-resistance properties, and the machinability and ductility for the straight chromium and the chromium–nickel types of stainless steel are discussed. The uses of stainless steel, in the architectural field, in the paper industry, in hospital equipment, and in the food, petroleum, transport, and aircraft industries are reviewed.—M. D. J. B.

Investigations of Constructional Material and Problems in this Sphere. W. Jäniche. (Stahl und Eisen, 1950, vol. 70, Mar. 2, pp. 174–186). An attempt is made to set forth the present state of knowledge regarding rail steel. The cause of cracks along the foot of flat-bottomed rails has been intensively studied. The August-Thyssen works has developed an up-hill casting procedure for rail ingots which produces rails of high surface hardness and low crack sensitivity. Fluctuating bending fatigue tests confirm the view that rail fractures are not usually caused by this type of stressing. A new type of repeated impact testing machine has been developed. The induction hardening of rails is receiving great attention and heat-treatment of rail ends to reduce wear is now an accepted process. Rail-testing methods and objects in the U.S.A., France, and Germany are discussed. In France radial cracks at the joint holes in the web have been eliminated by making the holes smaller and using fish-plate bolts of special steel. Finally, corrosion of rails in tunnels and near chemical works is considered; a copper content of 0·25–0·5% has proved beneficial in this respect.

R. A. R.

Segregation and Strength Properties of a Forging from a 56-Ton Ingot. S. Ammareller. (Stahl und Eisen, 1950, vol. 70, Feb. 16, pp. 125–133). Specimens were cut from a turbine rotor after many years' service to study the physical properties and segregation. The rotor had been forged from the lower part of a 56-ton ingot of molybdenum steel (C 0·37%, Mn 1·10%, Mo 0·28%). The extent of the segregation was much greater than that reported for killed steels in the literature, but this was probably due to the method of selecting samples. Manganese and sulphur balances showed that there was a surplus of manganese over that in solid solution plus that combined with sulphur. The analysis of the oxide inclusions revealed considerable amounts of MnO, particularly at the surface and the centre. The mechanical properties were in agreement with those in the literature. Elongation and reduction in area were at minimum values in the zones of segregation, but impact strength was only slightly affected in these zones.—R. A. R.

Necessity for Drawing Up Steel Specifications in Spain. (Boletin Minero e Industrial, 1950, vol. 29, Apr., pp. 203–204). [In Spanish]. The necessity for adequate technical documentation on steels and especially for standards for properties and uses, is stressed. A brief outline is given of the classification of carbon steels, based on conceptions of the leading steelmaking countries and it is suggested that the Spanish Ministry of Industry should draw up suitable standards which would facilitate the specification, ordering, and selection of steels.—R. S.

Strong Ductile Alloy Steel Permits Weight Saving in Structural Parts. D. A. Shinn. (Materials and Methods, 1950, vol. 31, May, pp. 70–72). In order to save weight in aircraft construction, aluminium, magnesium alloys, and the high-tensile steel SAE 4340 have been the standardized structural metals. A new patented steel, designated Hy-Tuf, which has high ductility and impact values at high strength levels, has now been produced by the Crucible Steel Co. (of America). A sample of this material containing 0·26% C, 1·26% Mn, 1·37% Si, 1·91% Ni, 0·09% Cr, and 0·43% Mo, has been compared with a standard sample of SAE 4340. Both steels were hardened and tempered to give a tensile strength of 230,000 lb./sq. in., in which condition their notched and unnotched fatigue strengths, impact values, and behaviour in the tensile test were determined at room temperature and at −320° F. The data indicate that Hy-Tuf has better notched-bar strength, ductility, and notched tensile strength, and possibly better low-temperature notched fatigue properties than SAE 4340 steel.—P. M. C.

Flow and Fracture Characteristics of a Die Steel at High Hardness Levels. L. J. Klingler, C. C. Chow, and G. Sachs. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1949, vol. 185, pp. 927–932; Journal of Metals, 1949, vol. 1, Dec.). A description is given of an investigation into the flow and fracture characteristics of a round bar of high-carbon high-chromium air-hardening steel, at various orientations and hardness levels. Results of tension, compression, and bend tests on specimens hardened and tempered at six different temperatures are given; from these it is concluded that: (1) Fracture stress and ductility in tension and bending show pronounced directionality, being higher in the longitudinal direction in each case; and (2) yield stress in tension does not vary with direction, and in compression varies only slightly. The directionality is attributed to mechanical anisotropy caused by carbide stringers developed in the fabrication of the material.—G. F.

Welded Structures of Steel with Different Plastic Properties. G. P. Mikhailov and A. Z. Solomonikov. (Avtogennoe Delo, 1948, No. 11, p. 15). [In Russian]. A description is given of tests in which 2-m. lengths of composite welded **H**-section beams of alloyed and low-carbon steels were successively loaded to 60, 75, 90, 100, 120, and 140 tons, the stress being determined at corresponding points in each material. The results obtained were used in the successful designs of welded structures which have been in constant use for a number of years incorporating alloy and low-carbon steels.—S. K.

A.L.S. Steel Manufactured by the Terni Works. A. Bartocci. (Costruzioni Metalliche, 1949, vol. 1, July–Aug., pp. 16–17; Sept.–Oct., pp. 18–24). The author examines the general characteristics of A.L.S. steel and the mechanical properties both obtainable and guaranteed. The steel can be supplied in strip, sheet, rolled sections, billets, forgings, and stampings. The chemical composition is discussed as well as the elastic limits, modulus of elasticity, brittleness, the heat-treatment properties, behaviour at low temperatures, ageing, and fatigue. The weldability of the steel is also considered and the results of numerous tests are given.—M. D. J. B.

A Statistical Study of the Influence of the Composition on the Mechanical Properties of Steel Sheets. M. Nepper and L. Dor. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Oct., pp. 331–336). Formulæ linking the relative quantities of oxygen, nitrogen, carbon, phosphorus, and sulphur with the tensile strength, hardness, ease of cold working, and bending and shaping properties are given. These were derived from test data relating to hundreds of specimens. The tensile strength and hardness can be characterized by $P + 5N_2$ (Stromeyer's formula). The ductility and cold-work properties depend very much on the nitrogen content and are related to $P + 10N_2$. The forging properties can be determined by $C + 2S + 10N_2$.—R. A. R.

Saving of Rolled Materials. S. Verner. (Hutnické Listy, 1950, vol. 5, June, pp. 227–233). [In Czech]. Possibilities of saving weight in steel sections by using higher-grade steels and better design of individual parts are investigated. In some cases different branches of engineering apply different standard specifications and safety factors to the same steel. E. G.

METALLOGRAPHY

The Structure of a Metal Surface. A. J. W. Moore. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept. 15, 1950). After a description of the Van der Waals forces and the chemisorption which can be predicted from the application of probability functions, this survey shows how metal surfaces encountered in practice compare with this simplified picture. Real surfaces show large irregularities in contour, fairly thick films of foreign atoms, and considerable deformation at or near the surface. The techniques for measuring these surface features and the types of result obtained from them are described. R. A. R.

The Effect of Diffusion on Structure in Alloy Systems. R. L. Kamm. (Australian Institute of Metals, Symposium on the Physical Bases of Impregnation Processes, Sept. 15, 1950). Most impregnation processes involve changes in microstructure of surface layers. The principles governing the formation of these new structures are described. After a theoretical discussion of the mechanism of impregnation and the uses of the laws of diffusion to calculate depth of penetration, the structures developed during impregnation of pure metals and binary alloys are treated using the equilibrium diagram although non-equilibrium conditions prevail. The deviations from equilibrium are described, and oxidation is treated in some detail.

Materials Problems in Production Solved with Microscope. R. Wachtell. (Materials and Methods, 1950, vol. 32, July, pp. 49–51). This article describes briefly seven cases of material failure which were explained by microscopical examination. The relevant microphotographs are reproduced in each case. Two of the materials are aluminium alloys, one a magnesium alloy, one aluminium, and the other three are steels.—P. M. C.

Grain Size Measurement. D. I. Cameron. (Australian Institute of Metals: Australasian Engineer, 1950, June 7, pp. 81–85). Three existing methods of grain-size measurement area: (*a*) To count the number of grains in a certain area (Jeffrie's Method), (*b*) the determination of the average width and breadth of grains (Heyn's intercept method), and (*c*) the use of comparison charts. The last named is the quickest and most convenient method, and for equiaxed material with grains of uniform volume, the existing charts are satisfactory. For elongated grains and mixed sizes, however, modified charts are desirable and a set has been constructed by the author. The proposed method of measurement is to use the A.S.T.M. grain size number as a single measure of the average area, followed by the ratio of the average length to average breadth, to denote the measure of elongation. The set of charts is reproduced.—P. M. C.

An Approach to X-Ray Microscopy. P. Kirkpatrick. (Nature, 1950, vol. 166, Aug. 12, pp. 251–253). Preliminary X-ray micrographs have been taken by total reflection at low glancing angles off two concave surfaces in planes perpendicular to one another. The faults of small field, oblique focal surface, and non-uniform magnification can only be overcome by a compound system of mirrors, the theory of which is little known. The theoretical resolving power is 70Å. and is independent of wavelength. Soft radiation is preferable, giving an increased critical angle and better contrast, but may necessitate using a helium atmosphere to lessen absorption. The method offers a wide range of penetrating power without the desiccating effect of the electron microscope. There is the possibility of microscopic chemical analysis using a series of monochromatic radiation bands.—A. G.

What One Can Expect from the Use of the Electron Microscope in Metallurgy. L. Habraken. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Aug., pp. 236–246). After a brief description of electron microscopy the author shows, with illustrations, how it has been applied to the study of the structure of fine powders and metallic surfaces. Investigation of the structure of nodular iron and chromium–molyb-

denum steels, and studies of the bainite transformation are among the applications which are reported.—B. G. B.

Detection of Feeble Magnetic Fields. Application to Electron Microscopy. R. Bernard and F. Davoine. (Comptes Rendus, 1950, vol. 231, Oct. 9, pp. 687–688). The apparatus consisting of a search coil (5 cm. in dia., with 20,000 turns), 2-stage amplifier, and detector (cathode-ray oscillograph) has a sensitivity of 10^{-5} oersteds. Slight disturbing fields in the electrostatic electron microscope are detected by its use and the elimination of these improves resolution from 50 Å. to 20Å., using a cold gas cathode.—A. G.

Electron Diffraction, the Diffractograph and its Application in Research Work. L. Wegmann. (Hutnické Listy, 1950, vol. 5, Oct., pp. 397–406). [In Czech]. Electron diffraction phenomena follow the same basic laws as X-rays; they can therefore be used to determine the shape of crystal lattices. These laws are briefly discussed and the arguments are amplified by comparing pictures obtained with an electronic microscope and a diffractograph. A description of a diffractograph made by Trüb, Täuber & Co., Zürich, is included. Many problems which are difficult to study by X-rays can be conveniently investigated by electronic diffraction. The diffractograph is particularly suitable for making a micro-analysis of very thin layers and also in optics where layers of a thickness of the order of a half or a quarter of the wavelength of light are involved. Another field is the study of the surface condition and finish of metallic and non-metallic specimens. Surface conditions differ greatly as a result of shaping and machining, the influence of oxidation, and the presence or absence of grease or other compounds. Professor Trillat (Paris) has designed a special attachment enabling him to follow in the diffractograph the changes in the surface condition of specimens during the process of heat-treatment. Professor Courtel has designed a polishing device which can be fitted inside the diffractograph and is intended for investigating the polishing process; he claims to have developed a polishing process for motor-car pistons which eliminates running in. Similar investigations were carried out on the wear of electric motor brushes. The diffractograph can also be applied to investigation of friction problems.—E. G.

Electron Microscope Examination of a Graphite Nodule in Cast Iron. H. Thyssen, P. Coheur, and L. Habraken. (Revue Universelle des Mines, 1950, Series 9, vol. 6, Mar., pp. 62–64). Photographs are reproduced showing clearly that the graphite nodule has formed around a minute particle or 'seed.'—B. G. B.

Application of Fractography for Judging the Properties of Low Carbon Steels. V. Zedník and Z. Kadérávek. (Hutnické Listy, 1950, vol. 5, Feb., pp. 45–51). [In Czech]. The authors investigated the plastic properties of ferritic steels by observing under the microscope the fractures of specimens broken in notch impact tests. Four steels of the following composition were used:

	(1)	(2)	(3)	(4)
Carbon, %	0·12	0·13	0·12	0·12
Manganese, %	0·43	0·44	0·42	0·42
Phosphorus, %	0·029	0·021	0·039	0·029
Sulphur, %	0·032	0·029	0·037	0·036
Copper, %	0·12	0·18	0·15	0·15
Chromium, %	0·01	0·07	0·03	0·01
Nickel, %	0·05	0·05	0·05	0·06
Silicon, %	...	0·19	...	...

Specimens were brought into conditions of great toughness, medium toughness, and brittleness by appropriate forms of heat-treatment. The results show that fractography is suitable for distinguishing between the degrees of toughness, as the ferrite has a characteristic appearance in each case. The technique can be used to determine the heat-treatment for a ferritic steel after cold working. Inter- and intra-crystalline fractures can be distinguished, and it will prove a useful tool for research on ageing.—E. G.

The Application of the Electron Microscope in Metallography. M. Rozsival, S. Vesely, and J. Chodorowski. (Prace Badawcze Glownego Instytutu Metalurgii i Odlewnictwa, 1950, No. 1, pp. 81–87). [In Polish]. The general principles of operation and characteristics of the electron microscope are given. Methods of preparing negative, positive, and metal vapour replicas are described. Photographs of heat-treated specimens, through the optical and the electron microscopes, are presented and clearly show the ferritic matrix with precipitated cementite. Some oxides at magnifications up to 25,000 are also illustrated.—W. J. W.

The Origin and Cause of Coarse Intercrystalline Fractures in Some Alloy Steels. V. Košelev. (Hutnické Listy, 1950, vol. 5, Aug., pp. 309–316). [In Czech]. Earlier observations led the author to the assumption that ferrite is an important factor in the occurrence of coarse intercrystalline fractures. To see whether this assumption is justified, tests were carried out to determine the relation between the intergranular structure and the microstructural changes occurring during cooling from high temperatures. A low-alloy steel was used (C 0·45%, Ni 2%). The specimens were heated to 1170° C., held for 8 hr. and then cooled at 200° C./hr. Specimens were quenched in water from various temperatures, differing in stages of 100° C. From 800° C. onwards the cooling rate was reduced to 5° C./hr. and the quenching temperature stages were reduced to 20° C. The quenched specimens were fractured for microscopical investigation. The author concludes that the tendency for formation of an intergranular fracture is a transitory phenomenon occurring in a certain phase of the production, and is not necessarily an inherent defect. If there are no cracks in the part, the tendency to intergranular fracture can be eliminated by heat-treatment. For a given example, the mechanical values obtained in a tensile test on a specimen with an intercrystalline fracture were practically equal to those of a specimen with a normal fine-grained structure.—E. G.

Electrolytic Isolation of the Carbides in Alloy and Unalloyed Steels. W. Koch. (Iron and Steel Institute, 1950, Translation Series, No. 412). This is an English translation of a paper which appeared in Stahl und Eisen, 1949, vol. 69, Jan. 6, pp. 1–8. *See* Journ. I and S.I., 1949., vol. 162, May p. 124.—R. A. R.

Notes on the Electrolytic Isolation of Carbides in Steel. G. Wranglen. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1949, vol., 185, pp. 919–920; Journal of Metals, 1949, vol. 1, Dec.). Factors involved in the electrolytic isolation of carbides in steel are discussed and special attention is given to the theory of Treje and Benedicks on the use of sodium citrate as electrolyte with the addition of bromine or iodine anions to exclude oxygen evolution at the anode. It is shown that the calculations made in support of this theory were erroneous, and that the anode potential, which is in fact negative in relation to the calomel electrode, need not exceed −0·3 to −0·2 V. Hydrochloric acid and ammonium chloride are suggested as suitable electrolytes.—G F.

Carbides in Isothermally Transformed Chromium Steels. W. Crafts and J. L. Lamont. (Transactions of the American Institute of Mining and Metallurgical Engineers, 1949, vol. 185, pp. 957–967; Journal of Metals, 1949, vol. 1, Dec.). An examination of the carbides present in three isothermally transformed 5–6% chromium steels, containing 0·20, 0·43, and 1·17% carbon respectively, is described. In this the specimens were held at 1150° C. for 30 min., transformed for various periods at temperatures ranging from 315° C. to 700° C., and finally water-quenched. Photomicrographs (× 2000) of the steels together with electron micrographs (× 25,000) of the electrolytically extracted carbides are shown, and X-ray diffraction data are also presented. It is shown that two forms of the carbide Cr_7C_3, differing in lattice dimensions, are formed, and an unidentified transitional constituent in pearlite specimens is indicated. The forms of carbide associated with pearlite are described and related to the different pearlitic structures. The study of the residues from bainitic specimens suggests that, although bainite may be formed in a manner analogous to martensite, there is a significant difference in the mechanism.—G. F.

'Bull's Eye' Formation in Blackheart Malleable Iron. J. Čeleda and Marie Ryšavá. (Hutnické Listy, 1950, vol. 5, June, pp. 221–227). [In Czech]. Investigations of 'bull's eye' formation (temper carbon surrounded by ferrite) in blackheart malleable cast iron was carried out by the laboratories of Ceskomoravska Kolben Danek with the following results: (1) A pearlitic rim always occurs in all castings from the same melt even if these are annealed in different pots, but castings annealed in the same pot may behave differently if they originate from different melts; (2) the thickness of the bright rim of a fracture is the same as that of the flake-free surface layer; (3) whilst the core of areas without bull's eyes

is pure ferrite, parts with a decarburized rim retain a partly pearlitic structure in the core after the annealing. All factors lengthening the incubation period, namely, chromium content, increased FeO in solid solution, and hydrogen cause bull's eyes, whilst factors which shorten the incubation times, *e.g.* increase in silicon, and inoculation, tend to suppress decarburization of the edges.—E. G.

The Beilby Layer. E. Bryjak. (Hutnik, 1950, vol. 17, May–June, pp. 113–118). [In Polish]. A historical survey of opinions on the structure of polished surfaces of metals is made.—V. G.

CORROSION

The Solubility of Iron in Hydrochloric Acid in the First Seconds. K. Wickert, E. Böhnert, and H. Pilz. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., pp. 106–107). Tests were made with Armco iron in *N*1, *N*2, and *N*10 HCl to ascertain the difference in solution rates in the first few seconds with and without an inhibitor. In *N*1 HCl the inhibitor's effect is much greater after 4 or 5 sec. than in the first 4 sec. In *N*2 HCl the corrosion rate with an inhibitor was about the same as with *N*1 HCl, but without it the corrosion rate was distinctly less than with *N*1 HCl. With the *N*10 acid the inhibitor had a very marked effect. In all the experiments the rate of solution in the first few seconds was rather high, due to the presence of very active cells.—R. A. R.

Metal Loss and Absorption. K. Wickert and J. Kroll. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., p. 105). Experiments are described in which the absorption of CO_2 dissolved in water by $Fe(OH)_3$ on iron was investigated. It was found that if the CO_2 in the water was physically absorbed by the $Fe(OH)_3$ coating, the corrosion of the iron was greater than with no coating, but if the CO_2 was chemically absorbed by the coating, the corrosion was less than with no coating.—R. A. R.

Degassing Waters to Prevent Corrosion. 4. Tests with the Oxidation of Sodium Sulphite with Molecular Oxygen in Condensates and Natural Waters. K. Wickert and E. Ipach. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., pp. 107–110). The oxidation of sodium sulphite to sodium sulphate in different waters with sodium chloride as an accelerator has been previously reported (*see* Journ. I. and S.I., 1949, vol. 163, Nov., p. 364). The use of other accelerators is dealt with in the present paper. Potassium permanganate is a powerful accelerator; its effect is less in alkaline than in neutral water. Metallic copper is also a good accelerator in condensates, but its effect is small in natural salt waters. In degassing waters containing sodium sulphite with potassium permanganate, the permanganate is instantly transformed into colloidal pyrolusite (MnO_2) which eventually settles, and it is the latter which acts as the accelerator. To remove all the oxygen from 150 cu. m. of water in 1 hr. requires a catalyst mass of 1 cu. m. of gravel containing 4·5% of pyrolusite (MnO_2).—R. A. R.

The Current Delivered by Galvanic Cells Due to Oxygen Supplied, as a Measure of the Oxidation and Initial Corrosion of Metals. F. Tödt. (Werkstoffe und Korrosion, 1950, vol. 1, Feb., pp. 49–51). The amount of oxygen reaching a platinum surface from an aqueous solution can be determined from the current in Coulombs which the platinum surface, as cathode connected with a non-polarizable anode, can supply. By reducing in stages the current from this cell in solutions of different oxygen contents, the surface of the metal can be supplied with quantities of oxygen between 10^{-9} and 10^{-12} gramme-equivalent per sq. cm. corresponding to a coating thickness of from several atomic layers to the thousandth part of a monomolecular layer. Even these thin oxygen layers, or oxidation, can be measured by currents of about $0{\cdot}2 \times 10^{-6}$ Coulomb/sq. cm. The results of such experiments can be applied to give a simple representation of corrosion phenomena. The initial corrosion of iron, copper, and nickel has been shown to be directly related to the current from such a cell.—R. A. R.

Testing Corrosion-Protection Media on Medical Instruments. K. Fischbeck and N. Müller. (Werkstoffe und Korrosion, 1950, vol. 1, Feb., pp. 52–56). Methods of preventing the corrosion of the inner surface of hollow needles of hypodermic syringes, and of scalpels have been investigated. Instruments were exposed in moist air, and in moist air containing hydrochloric acid, after one of the following treatments: (1) Boiling in water, (2) boiling in 3% soda solution, (3) boiling in 0·4% Passivin (sodium nitrite and soda), and (4) dipping in cold Passivin. The instruments prepared by treatments (2) and (3) were less susceptible to rusting than the others.—R. A. R.

Experimental Investigations of the Reactions between Steam and Iron. K. Wickert and H. Pilz. (Werkstoffe und Korrosion, 1950, vol. 1, Feb., pp. 56–64). An apparatus is described with which steam was passed over iron powder and filings of iron and different steels while at the same time the temperature at which the steam-iron reaction commenced and the pressure in the system could be measured. The temperatures at which the reaction commenced were: Iron powder of high activity 230° C., crushed iron powder 300° C., Armco iron borings 0·5–5 mm. 400° C., Armco iron filings 0·1–0·4 mm. 380° C., Armco iron filings < 0·1 mm. 340° C., 0·35% molybdenum steel filings 0·1–0·4 mm. 380° C., 0·41% carbon steel filings 0·1–0·4 mm. 380° C., chromium–silicon steel filings 0·1–0·4 mm. 510° C.; also filed plates of Armco iron 410° C., 22/1·15 chromium–silicon steel 780° C., 0·35% molybdenum steel 410° C., 0·41% carbon steel 420° C., and 20/14 chromium–nickel steel 780° C.

A specimen of Armco iron was oxidized at 600° C. in air for 30 min. and then treated with steam. The temperature at which the reaction began was 460° C. compared with 410° C. for unoxidized specimens. The application of the results to steels used for parts of the Benson boiler is discussed.—R. A. R.

High Pressures and Temperatures in Thermodynamic Applications.—II. S. Alvarez. (Dyna, 1950, vol. 25, Jan., pp. 1–19). [In Spanish]. The author describes the high-pressure experimental steam boiler at Purdue University and the results of some American work on enthalpy and other thermodynamic properties of steam at medium and high pressures. The corrosion tests carried out at Purdue on various steels subjected to steam at high temperatures, are described in some detail. Seventeen graphs and twelve tables are given. The conclusions are that the resistance of steels to corrosion by water vapour at temperatures up to 760° C. decreases with the content of chromium, especially from 7% downwards.

The degree of corrosion is greatest for the first 500 hr. and then progressively decreases. Steam temperature has a marked effect from 600° C. upwards, except in the case of the high-chromium steels.—R. S.

High Pressures and Temperatures in Thermo-Dynamic Applications—III. S. Alvarez. (Dyna, 1950, vol. 25, Feb., pp. 47–59). [In Spanish]. The article describes corrosion tests at Purdue University, carried out with steam on chromium–molybdenum steel and 18/8 steel bars subjected to mechanical stresses. The apparatus is described and a general account of the tests is given. The advantages of using steam at high pressures and temperatures are summarized and American advances are surveyed. Finally, a project for the development of Spanish research on the use of high-pressure and high-temperature steam is outlined.—R. S.

Resistance of Rustless Chromium–Nickel Steels to Corrosion in Commercial Sulphuric Acids. J. M. Defranoux. (Société Française de Métallurgie, Oct. 4, 1949: Revue de Métallurgie, Mémoires, 1950, vol. 47, June, pp. 447–453). Using a steel containing 0·1% of carbon, 17% of chromium, 10% of nickel, and 2·5% of molybdenum, the author has investigated the influence of impurities in commercial sulphuric acid on the corrosion of the steel in the diluted acid; the effect of additions of nitric acid was studied in detail. He found that certain conditions could be produced by additions of nitric acid that seemed to resemble the passive state, but the corrosion then was far from negligible; in this domain of so-called passivity the metal/solution potential appeared to contain a large factor depending on the oxidizing power of the solution. The corrosion of the steel examined depended very much on the amount of impurities in the acid; while some tended to increase the corrosion, others, notably nitric and nitrous compounds, decreased it.—A. E. C.

Practical Corrosion Investigations on Low-Pressure Steam Heating Systems. G. Seelmeyer. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., pp. 93–102). The results of corrosion investigations on 46 low-pressure steam-heating systems in Germany are reported, special attention being given to the effect of the *p*H value and composition of the condensates.

Corrosion Problems in Powder Metallurgy. H. Grubitsch. (Werkstoffe und Korrosion, 1950, vol. 1, Mar., pp. 89–93). The local-cell corrosion of metals in general and the special corrosion problem raised by the porosity of powder-metallurgy parts are discussed. Recommendations for protective coatings are made. Coatings with a solvent which evaporates should not be used. Paints containing drying oils or polymerizing synthetic resins are recommended. The parts should not be acid-pickled, but rust can be removed by sand-blasting before painting. Phosphatizing should only be applied when the pore volume of the part is less than 10%.—R. A. R.

Stress-Corrosion Cracking in Stainless Steels. I. Practical Experiences. II. An Investigation of the Suitability of the U-Bend Specimen. H. Nathorst. (Jernkontorets Annaler, 1950, vol. 134, No. 3, pp. 97–133). [In Swedish]. An extensive collection has been made of the experiences in Sweden on stress-corrosion cracking of stainless steels in practical use. The cases are divided into three groups, the first comprising liquids containing chlorides, the second group alkalis, and the third one miscellaneous reagents. The first group also contains cases where there is reason to suppose that the chloride content has been the determining factor for the attack by the reagent. Among the cases studied are heat-exchangers for the dairy industry, coils in quenching baths, plate coolers in a sulphite pulp mill employing sea water, vacuum evaporators for zinc chloride, boilers and evaporators for sodium hydroxide, and equipments used in the sulphate cellulose production. In group three, corrosion due to sodium hypochlorite, orthodichlorobenzene, and pine resin, among others, was investigated. An account is also given of different cases related in the literature. The reproducibility of tests using **U**-specimens of 1·5-mm. 18/8 steel sheet, immersed in hot concentrated calcium chloride solutions, was investigated. A comparatively high degree of reproducibility may be obtained if the test pieces are prepared very carefully and the specimens are stabilized, *i.e.*, stressed and kept at 150° C. for 14 days. It was even found that calcium chloride of different origin and purity varies considerably as regards corrosivity. Certain objections against the **U**-bend test were raised by the author.—B. S. E.

ANALYSIS

Conductometric Method for Determination of Carbon in Steel. E. L. Bennet, J. H. Harley, and R. M. Fowler. (Analytical Chemistry, 1950, vol. 22, Mar., pp. 445–448). The apparatus for determining small amounts of carbon in steel consists of an oxygen purification unit, a combustion furnace and tube, sulphur-removal unit, and measuring bridge. The CO_2 in the oxygen is absorbed by barium hydroxide solution the electrical conductivity of which changes with the amount absorbed. The results obtained compare favourably with those obtained by the more time-consuming combustion and gas-fractionating apparatus.—R. A. R.

Determination of Carbon in Ferrous Alloys. R. M. Fowler, W. G. Guldner, T. C. Bryson, J. L. Hague, and H. J. Schmidt. (Analytical Chemistry, 1950, vol. 22, Mar., pp. 487–488). In a round-table discussion each of the above speakers described the apparatus used in his laboratory for determining carbon contents of less than 0·10% in ferrous alloys.—R. A. R.

New Analytical Applications of the Reaction : $HgO + H_2O + 2XK = X_2Hg + 2KOH$. Acidimetric Determination of Cobalt. F. Burriel Marti and F. Pino Perez. (Anales de la Real Sociedad Española de Fisica y Química, 1950, vol. 46B, Feb., pp. 101–104). [In Spanish]. A new volumetric technique for the determination of cobalt, based on conversion to cobalt cyanide is described. The potassium cyanide addition is acidometrically evaluated after adding HgO. The author claims that his results show that this volumetric method is more sensitive and accurate than existing methods. Its disadvantage is that it cannot be applied in the presence of those elements which, in practice, accompany cobalt.—R. S.

Determination of Copper in Iron and Steel as the Thiocyanate. L. H. James. (Chemist Analyst, 1950, vol. 39, Mar., pp. 9–11). The proposed procedure is similar to one recommended by N. W. Lord and D. J. Demorest for the estimation of copper in ores. It is possible to determine first the chromium and silicon as suggested by F. W. Scott, and then use the filtrate thus obtained for the determination of copper.—R. A. R.

Determination of Selenium in Stainless Steel. N. S. Mott. (Foundry, 1950, vol. 78, Feb., p. 121). The following gravimetric method is recommended : (1) Dissolve 5 g. of drillings in a mixture of 30 c.c. conc. HNO_3 and 30 c.c. of conc. HCl, adding about 2 c.c. of 48% HF. After violent action ceases, heat gently until all is dissolved. (2) When in solution add 40 c.c. of 60% $HClO_4$ and take to strong fumes. (3) Cool and dilute to 250 c.c. with hot water. (4) Add simultaneously 20 c.c. of 25% aqueous solution of hydroxylamine-hydrochloride and 100 c.c. of conc. HCl. (5) Digest on steam bath for 1 hr. (6) Filter in a Gooch asbestos-lined and ignited crucible, washing well with hot water. (7) Dry at 105° C. for 1 hr., cool well and weigh. (8) Ignite to expel selenium, cool well, and weigh ; the difference in weight is selenium. For selenium values under 0·10%, treat two or more 5-g. samples as above and finally filter all on the same Gooch crucible.—R. A. R.

BOOK NOTICES

BABLIK, H. "*Galvanizing* (*Hot-Dip*)." Third Edition. 8vo, pp. xiv + 502. Illustrated. London, 1950 ; E. & F. N. Spon, Ltd. (Price 70*s*.)

Dr. Heinz Bablik's book, originally published in Vienna in 1923, is established as the standard work on galvanizing so that the appearance of the third edition is an event of some importance. The book has been completely rewritten and is confined to hot-dip galvanizing ; it has been considerably enlarged to include recent research and process information. In fact, considering the handicap of his separation from progress in many countries during the Second World War, Dr. Bablik has brought his book remarkably well up-to-date. Those familiar with the second edition will appreciate the work necessary to achieve the new edition, especially the very difficult task of translation, well done considering the scientific and technical nature of the text.

Dr. Bablik is well fitted as author, because of his direct connection with the industry as manager of the galvanizing works inherited from his forebears and his scientific approach to the practical aspects of the industry.

Chapters 1, 2, and 3 deal exhaustively with scale, and pickling theory and practice, and are recommended for study by those responsible for cleaning and pickling operations in the steel industry and in the finishing industries where the preparation of steel surfaces is of fundamental importance. Dr. Bablik discusses the main types of scale such as furnace scale, mill-scale, and annealing scales, and indicates the relative difficulties associated with their removal. The influence of factors such as temperature on the structure of scale and its relation to solubility are outlined. It should be mentioned that deoxidized surfaces produced by the cold-reduction process need some pre-treatment for galvanizing and that this should have careful control, assisted by protection with restrainers. The need for careful treatment by pickling was realized early because of 'undesirable subsidiary effects' such as excessive etching and solution of the steel base, and the diffusion of hydrogen with the subsequent formation of blisters and its effect on the formation of the zinc coating. The degree of pickling and its relation to the chemical and physical characteristics of the steel base are indicated by the spangled surface. The treatment of waste pickling liquor is discussed (p. 96) and the need to neutralize before running into streams and rivers is emphasized. Mention should be made of more recent work on the crystallization of the iron sulphate so that free acid is returned to the pickling tanks and the roasting of ferrous sulphate to produce sulphuric acid by the autoxidation process, investigated by the British Iron and Steel Research Association Laboratories at Swansea. The special processes such as jet pickling, electrolytic pickling, salt fuses, and gas pickling are mentioned. The description of pickling plant is fully treated.

In Chapter 4 the purpose and nature of fluxes are dealt with in some detail. There is need for research to deter-

mine a suitable flux for aluminium-treated baths (p. 155). Chapter 5 on galvanizing theory is especially well developed and corrosion is dealt with (p. 310). The treatment of the influence of added elements to the bath is exhaustive, but it is clear that considerable research is needed to present a true picture of the effects of solitary elements and the accumulative influence of several elements. The addition of aluminium is discussed (p. 204). It is recommended that Dr. Bablik's discussion should be augmented with a study of Dr. Hughes' paper (*See* Journ. I. and S.I. 1950, vol. 166, Sept., p. 77) in which the theories concerning the effects of aluminium, such as the presence of a membrane or the formation of non-adherent alloys, are analysed and a new theory indicating the presence of a restraining Fe–Zn–Al alloy is formulated.

Chapter 6 is an outstanding contribution to the literature of galvanizing practice which will be appreciated by those responsible for production and its many associated problems of design, materials, and heating. The value of ingot iron for tank construction is confirmed (p. 387). The description of the galvanizing processes (p. 417) is commended; the lead-zinc process, dry-galvanizing, galvannealing, machine galvanizing leading to semi-continuous and continuous strip galvanizing and the Sendzimir process, and the galvanizing of pipes, wire, wire cloth, hollow-ware, and sintered iron are described.

The Sendzimir process (pp. 19, 116, 156, 285, 442), a development of much importance, in which the cold-reduced strip is pretreated by oxidation and subsequent reduction, annealed, and partially cooled in a protective atmosphere and passed direct to the zinc bath, is described. Dr. Bablik's theory that nitrogen is to some extent responsible for the very good adhesion is not proven. The rôle of aluminium in the bath is probably more important. The surface treatment of coatings by the application of chromate solutions is discussed and the examination of coatings is outlined.

It should be mentioned that the intensive research work on hot-dip galvanizing proceeding in the laboratories of the British Iron and Steel Research Association and the British Non-Ferrous Metals Research Association, and especially the development of equipment and the continuous processes in the U.S.A., will necessitate further revision in the near future.

The book would be improved by having an author and subject index because the text is well stored with practical and theoretical information. The book is clearly printed and profusely illustrated especially with photographs of industrial processes.

Dr. Bablik's book will enhance his reputation as one of the foremost authorities on the subject of galvanizing in the world and is recommended for everyone connected with this interesting and important industry.

HAROLD EDWARDS.

BRISCOE, H. V. A. and P. F. HOLT, "*Inorganic Micro-Analysis.*" 8vo, pp. viii + 171. Illustrated. London, 1950: Edward Arnold. (Price 12*s.* 6*d.*)

This small textbook was written to help the person who feels that he could make use of the elegant techniques of inorganic micro-analysis, but who is not able to find facilities for the necessary training. The methods presented have been given extensive practical test, and will give reasonable results in the hands of the student.

The first half of the book deals with qualitative micro-analysis. After two chapters on general technique a scheme of qualitative analysis is presented, followed by a chapter on the reagents used and the mechanisms of their reactions. The elements covered in the scheme of analysis are those encountered in the Intermediate B.Sc. practical course, and the so-called "rarer elements" such as molybdenum and vanadium are not included.

The second half of the book deals with quantitative micro-analysis. After an introduction, five chapters deal in turn with gravimetric, volumetric, diffusion and gasometric, colorimetric, and combustion methods. The final chapter of the book gives detailed instructions for one or more determinations in each of the above groups.

The methods presented (with the exception of the colorimetric methods) require no expensive apparatus, and they all show clearly the simplicity, speed, and convenience of micromethods which are so often the factors in causing them to displace the older macromethods.

When a person has read this book and obtained some practice in micromethods he wants to see if his own problems can be solved in this way, and the absence of a bibliography and of some indication of the accuracy limits obtainable with micromethods is to be regretted.

The book is well bound and printed, with the exception of the semimicro logarithm tables, which are not at all easy to read.—J. B. BOOKEY.

DAVIES, W. "*Foundry Sand Control: Testing, Research and Development.*" 8vo, pp. x + 212. Illustrated. Sheffield, 1950: The United Steel Companies, Ltd. (Price 30*s.*)

There is no doubt that Dr. Davies and the United Steel Companies Ltd., have by this publication made a valuable addition to the library of the steel-foundry technologist. The joint efforts of Dr. Davies and the late Dr. W. J. Rees during the war years in particular are already known to many who will welcome 'Foundry Sand Control' as a permanent record of their work, quite apart from the very much wider value of the volume as an authoritative up-to-date work of reference in this important field.

In 12 chapters Dr. Davies deals clearly and adequately with the mineralogy of sands and clays, with the theory of the clay bond and with the fundamental factors influencing moulding sand characteristics. His lucid treatment of the many fundamental considerations upon which intelligent foundry sand control must necessarily be based, will be well received by the steel-foundry industry.

No one will disagree with Dr. Davies' firm view that foundry sand control should anticipate and correct conditions likely to cause trouble rather than provide a means of 'post mortem' investigation. There must be less ready agreement, however, with the somewhat idealistic suggestion that with the extended development of foundry sand control it should become both possible and practicable to define precisely the physical and mechanical characteristics of mould materials which will be best suited to each individual casting problem. The inference from this is that the foundry of the future might be expected to specify and to vary the properties of its moulding and core sands from one casting to another, depending upon the characteristics envisaged as being necessary to the production of a casting free from the various defects which can arise from faulty sand practice. It is felt that the present trend of thought among steel-foundry technologists would more probably lean towards attending appropriately to the design of the casting itself, to the location of feeder heads and gating arrangements, and to the use of proved devices such as external chills or brackets, rather than the introduction of further hazard from varied moulding sand properties within any one production unit.

Dr. Davies' suggestion in this direction must, however, not be decried nor adversely criticized, for the more closely the consideration of mould form is associated with the drawing office, the better and more commonly accepted this approach to foundry technology becomes, and the more rational and predictable will foundry operations be. Steel foundrymen should not expect to find in Dr. Davies' book a series of solutions to all the day-to-day practical problems with which they are likely to be faced, but they can find the means of providing themselves with the type of background which should enable them more competently to employ available mould and core sands and with a greater certainty to detect and avoid the causes of trouble which they may from time to time come across. Dr. Davies, it should be mentioned, apart from making passing reference and from giving suitable definition, does not deal with oil-bonded sands nor with the many forms of core-binder of proprietary origin in this field.

The book contains a carefully selected bibliography relating to each chapter and the Appendix refers to a comparison of various methods of indicating diagrammatically the grading of sands, to the identification of clay minerals, and to the relation between bond proportion and the bond strength of synthetic sand.—J. F. B. JACKSON.

GOETZEL, C. G. "*Treatise on Powder Metallurgy.*" Volume II. "*Applied and Physical Powder Metallurgy.*" 8vo,

pp. xviii + 910. Illustrated. New York, 1950: Interscience Publishers Inc.; London: Interscience Publishers, Ltd. (Price £7 4*s*.)

The present volume completes the textual part of Dr. Goetzel's "Treatise on Powder Metallurgy," since the third volume that is still to come will contain only a classified bibliography of the literature and patents.

In some 1650 pages the author has succeeded in presenting a complete picture of the subject, and it might almost be added, complete in every detail. However, throughout the two volumes there is not only a minimum of overlap, but also a highly commendable absence of padding. The author has drawn his data seemingly from every known source, and has then applied considerable skill and discretion in the marshalling of his facts. Not one important error has been detected, and the only fault that one might find with the book is its exceptionally high price. At the same time, as a standard work of reference, the three volumes should be indispensable to anyone engaged in the powder-metallurgy industry, since it is safe to say that this 'Treatise" will not be superseded for many years to come.

Volume I dealt with metal powders and the various techniques of pressing and sintering, including equipment. The first half of the present volume covers all known products, whilst the second half contains a number of chapters that have been grouped together under the name of 'physical powder metallurgy.' To take these latter first, the physical properties of sintered and fused metals and alloys are compared with the object of aiding the engineer in evaluating and selecting his materials of construction (31 pages). Then follows a comprehensive survey of potential applications, as distinct from current applications, of several hundred alloy systems divided into nine groups according to their industrial usefulness (136 pages). The next chapter discusses the stress analysis of sintered metal, that is to say, the inherent effect of porosity on the physical properties of metals (15 pages), and from the same point of view the value of the various testing methods is appraised (29 pages). Between this and the final chapter reviewing the future possibilities of powder metallurgy (12 pages), the author has inserted a survey of all existing theories of bonding and sintering (64 pages). Though it seems to be rather out of place in the second volume, it is nevertheless very well written and admirably presents the existing state of the theoretical knowledge of the subject.

Now to return to the first part of this volume entitled 'applied powder metallurgy.' The author discusses the following subjects very competently and comprehensively: Refractory metals and alloys (70 pages), electrical contacts (49 pages), magnetic materials and products, including soft magnetic components (35 pages), a well-written and long chapter on hard metals and compositions including diamond compositions (105 pages), a survey of the sintered iron and steel position, with particular reference to alloy steels and the techniques of infiltration (136 pages), a rather brief review of the non-ferrous structural part position (66 pages), porous products including bronze and iron bearings, filters and wear-resisting products (40 pages), friction materials (16 pages), dental alloys (6 pages), and a review of miscellaneous applications of metal powders (12 pages).

The book has been excellently printed, with copious illustrations, diagrams, and tables, and the publishers are to be congratulated upon the high standard of their production.—W. D. Jones.

Weber, R. L. "*Heat and Temperature Measurement.*" 8vo, pp. x + 422, 27 tables. Illustrated. New York, 1950. Prentice-Hall, Inc. (Price $6.65)

This book describes methods of heat and temperature measurement and includes the theoretical principles necessary for their appreciation, intelligent use, and extension. It has been written as a textbook for college students, and, to quote the author, the material will appropriately follow an introductory physics course, and is suitable for a one-semester college course in which lecture and laboratory work are integrated. Throughout the book the emphasis is on experimental methods rather than on thermodynamic theory, and for this reason it should also appeal to all technicians whose work is in any way connected with heat and temperature measurement.

The first part of the book, containing 15 chapters, presents the physical principles which serve as a basis for thermal measurements. Each chapter is followed by a set of problems and by a list of references to appropriate scientific journals. The subject matter of the first part of the book may be summarized as follows: Temperature scales, expansion thermometers, heat transfer, thermoelectricity and thermoelectric temperature measurements, radiant energy, optical and radiation pyrometry, resistance thermometry, temperature recording and control, calorimetry, phase diagrams, thermodynamics, extreme temperatures, and special methods of temperature measurement.

The second part of the book outlines the procedures for 29 typical laboratory experiments. Photographs of recommended apparatus and diagrams of its layout should prove of great value to students working through these experiments.

The book is excellently produced, printed on very fine quality paper, and is well laid out, illustrated, and easy to read. This reviewer can confidently recommend it to all those, students or technicians, whose work includes an understanding of heat and temperature measurement.
P. M. Cook.

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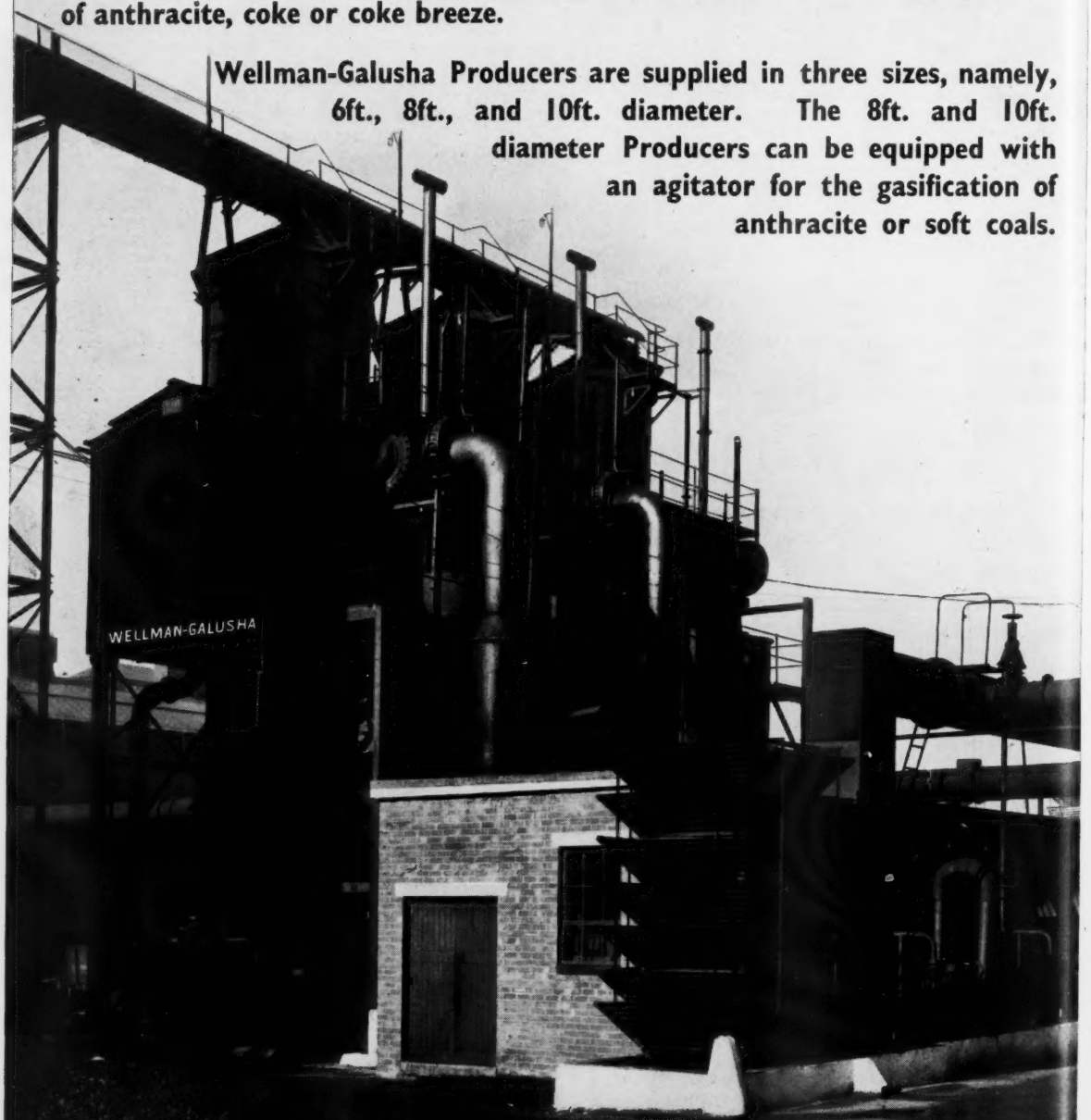

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ALBERT JACKSON, F.I.M.

ALBERT JACKSON was born in Scunthorpe in 1905 and received his early education there. He was awarded a scholarship by the Lincolnshire Ironmasters' Association, tenable at Sheffield University, and obtained an Associateship in Metallurgy in 1925. He joined the Appleby-Frodingham Steel Company as a chemist in 1920, and apart from the period spent at Sheffield University has since remained continuously on the staff of the Company.

In 1927, following a year in the Metallographic Laboratory, he joined the staff of the Melting Shops as an Assistant Manager, coincident with the opening of the new Appleby plant.

In 1935 he was responsible for the formation and operation of the Works Metallurgists Department, which was designed to concentrate, under one head, the study of steelmaking and rolling problems in relation to steel quality. A little later he became Manager of the Slabbing Mill, and in 1936 he was appointed Manager of both the Company's Melting Shops.

For a period of eighteen months, following the end of World War II, Mr. Jackson was on loan to the Control Commission for Germany in an advisory capacity on iron and steel plants. During this time he made a wide survey of German plants in all four zones of Germany, the last few months being spent as a member of a four-power inter-allied Commission, assessing plant capacities.

Prior to this German visit he had seen the plans completed for the new Frodingham Melting Shop, and his return saw construction well in hand. He was appointed Melting Shops Superintendent, and for the first year he was engaged essentially in the organization and starting up of this new plant, which came into operation in November, 1947.

In 1948 he became Works Manager (Steel) and was then responsible for the Company's plate and section mills, in addition to the Melting Shops. In 1951 he received the appointment of Deputy General Works Manager.

Mr. Jackson has been prominent, locally, in the field of technical education. From 1929 to 1936 he was lecturer in Metallurgy at the Scunthorpe Evening Technical School, and since that time he has given many lectures to operatives engaged essentially in steelmaking. For many years he has been a member of the Metallurgy Advisory Committee of City and Guilds of London Institute and serves, in a similar capacity, the Scunthorpe Technical College.

Mr. Jackson has read many papers before various technical societies throughout the country, his main interests being the basic tilting process, ingot moulds, and the effects of steelmaking variables on semi-killed ingots. Several papers have been published in the ***Journal***, and in 1942 he was awarded the Williams Prize for his paper on "Linings of Large Basic Open-Hearth Tilting Furnaces."

He has been a member of the Council of the Lincolnshire Iron and Steel Institute since 1933, and was a Vice-President for many years before being elected President in 1950. He was awarded a Fellowship of the Institution of Metallurgists in 1946. A Member of the Iron and Steel Institute since 1934, he became an Honorary Member of Council in 1950.

Albert Jackson, F.I.M.
Honorary Member of Council